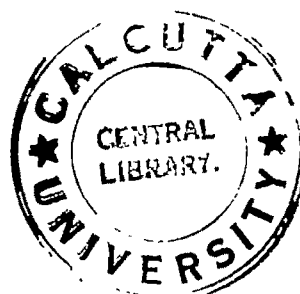

PROCEEDINGS OF
THE IGU SYMPOSIUM

PROCEEDINGS OF
The IGU Symposium
On Hydrel & Thermal Power Development
in the Developing Countries

CALCUTTA 1968



Director of the Symposium
KANAN GOPAL BAGCHI

Organised by
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CALCUTTA UNIVERSITY
&
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Participants in the Symposium belonged to the following
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1. Bhagalpur University, Bihar, Department of Geography
2. Burdwan University, Chandernagore Government College
3. Calcutta University, Department of Geography
4. Gorakhpur University, Department of Geography
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6. North Bengal University, Siliguri College
7. North Western University, Evanston, Illinois, U.S.A.,
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8. Rajasthan University, Department of Geography
9. Visva Bharati University, Department of Geography

Organisations :

10. Bangiya Sahitya Parishad
11. Damodar Valley Corporation
12. Geographical Society of India
13. Indian Statistical Institute, Calcutta
14. Irrigation and Rain Research Institute, Patna
15. Students Geographical Association, (Post-Graduate
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Government of India :

16. Central Water and Power Commission
17. Coal Board
18. Defence Academy, Kharakvasla
19. Indian Meteorological Department, Calcutta
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| Power Potential | — Prof. N. N. Chatterjee, University of Calcutta |
| Power Development | — Prof. S. C. Bose, Gorakhpur University |
| Power Utilisation and Perspective Planning | — Prof. N. K. Bose, Commissioner of Scheduled Castes and Tribes, Government of India |
| Concluding Session | — Prof. E. B. Espenshade, North Western University, Evanston, Ill., U.S.A. |

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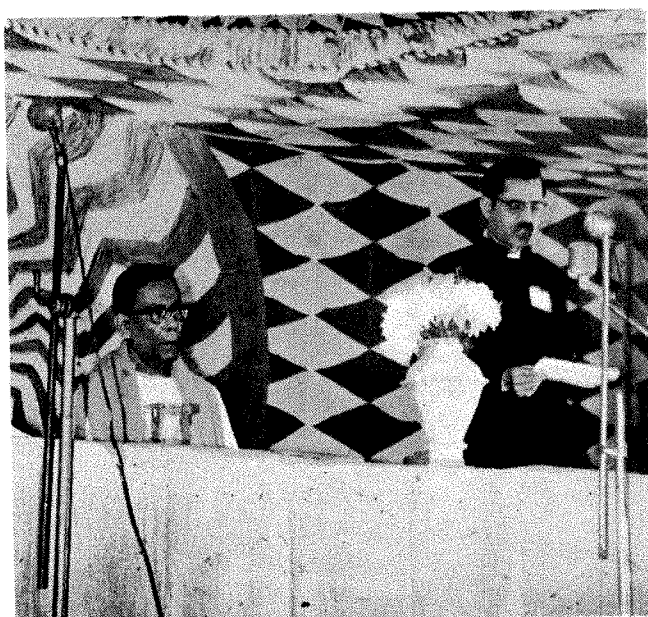
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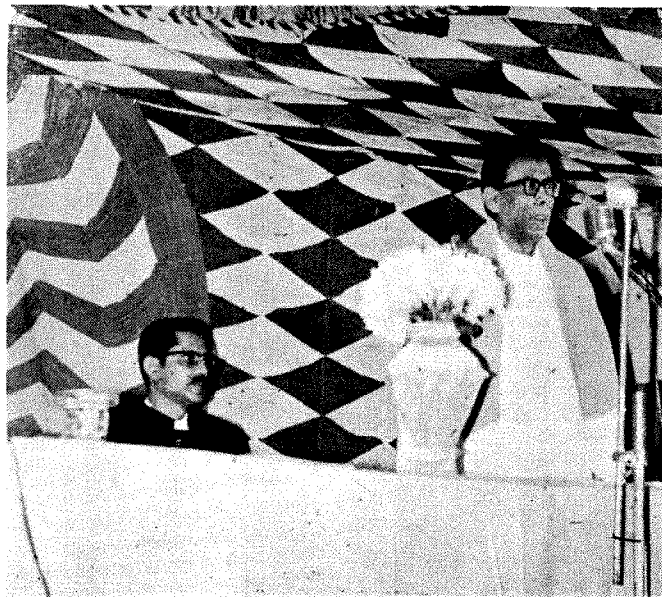
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1. Sri K. Bagchi inviting the Vice-Chancellor



2. Dr. S. N. Sen. inaugurating the symposium



3. Dr. P. K. Bose, addressing the symposium



4. Dr. E. B. Espenshade, addressing the concluding session



5. Delegates on way to Mor Multipurpose Project



सिंचाई व बिजली मन्त्री, भारत
MINISTER FOR IRRIGATION & POWER
INDIA

नई दिल्ली,
New Delhi, 20th November, 1968.

M E S S A G E

I am very happy to learn that the University of Calcutta is organising a Symposium on 'Hydel and Thermal Power and its Geographical Implications in Developing Countries' in collaboration with Geographical Society of India from 26th to 29th November, 1968, to celebrate the occasion of the International Geographical Congress which is being inaugurated by our Prime Minister in New Delhi in the first week of December, 1968.

The harnessing of power resources of a country's hydel or thermal generation, so vital to its industrial and agricultural economy, is closely influenced by its geographical features and in turn influences the geography of the region. The formulation of plans for economic development necessitates the optimum use of water, land and mineral resources of river basins, and has to be on a fully comprehensive basis keeping in view all significant resource uses such as : water for domestic, municipal, agricultural and industrial uses ; power generation, navigation, flood protection, drainage ; forest and mineral production, grazing and crop land improvement, wild life protection, preservation of areas of natural beauty etc. Knowledge of geography is thus of importance to engineers and planners alike and we look forward with interest to the deliberations of your Symposium.

K. L. Rao
(K. L. Rao)

Shri K. Bagchi,
Head of the Deptt. of Geography
and Chairman, Organising Committee,
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SENATE HOUSE
CALCUTTA-12
7th May 1970

FOREWORD

The subject of power resources is so very important from the point of view of the economic development of a country that I was naturally interested in the proceedings of the Symposium of "Hydel and Thermal Power and its geographical implications, in developing countries" organised by the Department of Geography of our University. The coverage of the Symposium has been wide, and a large number of the different aspects of this problem have been studied by different scholars who have presented papers. The writers of these papers have also been selected carefully so as to represent different sectors of the academic and the professional world. There are teachers of the Universities, of the affiliated colleges, and of other teaching institutions, research scholars, professional economists, planners and engineers. The pooling together of so many brains with considerable experience in different fields has resulted in the production of this rich fare. I am sure that this cross-fertilisation has improved the tone of discussion and has served to produce a crop of new ideas with great potentialities. The geographical conditions of the country have no doubt influenced the relative distribution of power resources of various types, resulting in some cases in maldistribution. But as this Symposium has shown, this geographical inequity can be remedied through well-planned schemes of utilisation of the potential power resources of this country. This volume of papers is bound to have its impact on the development of new ideas, repolishing of old themes, and on the formulation of plans for the development of the resources of the country.


(S. N. Sen)

P R E F A C E

The symposium on Hydel and Thermal power in the light of geographical implications was organised by the Department of Geography, University of Calcutta in collaboration with the Geographical Society of India from November 26 to 29, 1968, and was financed by the University Grants Commission, New Delhi. The symposium formed one of the items (S 28 of I. G. U. News letter) amongst numerous celebrations in connection with the International Geographical Congress held in the capital of India in December of the same year, Professor S. P. Chatterjee, former head of Geography of this University presiding.

Power constitutes the single most important factor contributing to the build up and forward drive of a developing economy and is a measure of the progress achieved. India attained independence in 1947. The installed capacity, which was 162,341 KW in 1925 grew up to 900,402 KW in 1945—an increase of five fold only in two decades. The picture was indeed a dismal one, as it still is in many of the countries dispersed over the now fragmented gondwanaland. The urge for economic growth, immediately after achievement of independence, spurred on power development in the country and the figures stood at 5,779,795 KW—an increase of nearly 215 percent over the situation in 1951. J. W. Meares had made a rough calculation of the Water Power Potential of India varying in range from 3.5 million KW at the minimum to 8 million KW at the maximum. Refined calculations by the Central Water and Power Commission took this to 41.5 million KW and this too cannot be the last word as improved techniques are pressed into service. The almost unlimited potential of thermal and nuclear power free us, consistent with our technological progress and economic sustenance, from all restrictions to make power available to the desired extent. By the end of the 4th plan, with Tarapore already in the grid, we shall be generating 22 million KW.

Power resources are unequally distributed over India. Coal, the primary source of thermal power, so far, is mostly confined to the valleys of the Damodar, Mahanadi and the Godavari. The states concerned are Bihar, West Bengal, Orissa, Madhya Pradesh. Utilising lignite and tertiary coal we might bring Rajasthan, Tamilnadu and Meghalaya into the fold. Melted snows coupled with precipitation—the two combining to yield perennial hydro power—are confined to the Himalayan streams which traverse the seismic terrain. The Western Ghats, the Palnis, the Shevaroy, and the Eastern Ghats provide considerable hydroelectric potential, a large part being already energised, but the efficacy is entirely dependent on the monsoons. Probing of the atmospheric complexities and seeding of the clouds may contribute to the efficiency margin but, on the whole, monsoons will remain monsoons with characteristic unpredictability and alternate stand-bys will ever remain imperative. Then we have Rajasthan, Gujarat and the coastal tracts unfavoured in varying amounts geologically, topographically and also to a great extent climatically from traditional thermal and hydro sources. Hence the need for atomic power—however costly at the outset. The Tarapore, Kota and Kalpakkam will revolutionise our power potential, but much more important than this, our power fluctuation in days of drought, infusing confidence in industry and agriculture.

The future may be bright but the present is full of challenges. Current arrangements of transmission are centred round areas of intensive current consumption e.g. in the coal-steel belt of Eastern India, in the Hooghly industrial hub, the Bombay industrial sector, the Madras-Mysore industrial area, the Khabra industrial belt in U.P. and the Delhi-Punjab industrial area. There are vast regions, particularly in the North-Eastern India, in Tripura, Manipur, Assam, NEFA, Nagaland and Meghalaya which are crying hoarse over power. If power is needed for industry and transport, power is more essentially needed for our agricultural operations. True, some progress has been made in this direction. By end of third plan 1.1 million

pumps were energised by electricity for irrigation and by the end of the Fourth plan 1.25 million more pumps will be added to the list. The droughts in Bihar and the adjoining plateau districts of West Bengal which shook the nation and the countries beyond has brought this into focus. It is even questioned whether the priority for irrigation should vest in the water that flows on the surface or oozes out from underground. May be the ground water is a safer and more lasting source when the monsoon withdraws its smiles.

Closely tied up with power is the scope of rural employment. The people in villages must have an alternative employment since agriculture, however developed, would fail to absorb many more people. Although from a mere 5,000 the number has moved up to 43,000 in 1966 and nearly 60,000 in 1968, the target for the Gandhi Centenary year of 1 lakh villages yet remains to be achieved. And unless the villages are electrified the employment problem cannot be solved. The question of distribution of power, then, becomes a matter of national importance and the national grid a must for our planners.

This department therefore has welcomed the suggestion of the I. G. U. to organise a seminar on Power. One of the Professors of this University, late Dr M. N. Saha was a pioneer in the field of planning and has sponsored all moves to further the cause of multipurpose river valley projects till the last day of his life. As one of his close associates in the study of river basins I too had crusaded for developments of river valleys on a sound basis. For well nigh a decade I had been functioning as an expert in the Diagnostic Survey of the Damodar Valley Region set up by the Ministry of Irrigation and Power at the instance of the Planning Commission. It has been a pleasure for me to have enlisted the participation of a large number of specialists in this symposium. It was indeed generous of our Vice-Chancellor, Dr. S. N. Sen to have provided encouragement and counsel in this venture whenever sought. He even spared his valuable time to come over to the Science College premises at Ballygunge to inaugurate

the symposium, stressing in the course of his address the significance of power in a developing economy and the lines along which power should be developed. Dr. P. K. Bose, the Pro Vice-Chancellor (Academic) extended his patronage and took a keen interest in our activities. His advice at the inaugural session was to consider different aspects of power, generation, distribution and consumption as an interdisciplinary field of discussion in which engineers, geographers and geologists, statisticians and economists all play vital role. Dr. D. Chakravorti, the then Dean of the Faculty of Science of this University who also graced the occasion of the inauguration, recounted the contribution of scientists of this University, particularly those of late M. N. Saha and B. C. Guha in taking us out of the colonial economy through a revolution in power generation. Incidentally he dwelt on the sustained interest evinced by the present Head of the Department of Geography through his various writings and discourses in the matter of scientific uses of hydrological resources of the country. The first session was presided over by Prof. N. N. Chatterjee of Calcutta University, who has made valuable contribution in the field of Indian coal. The second session was presided over by Prof. S. C. Bose of Gorakhpur University, a specialist in regional and resource geography of India. The third session was presided over by the director of the Symposium himself when Dr. H. Banerjee of Jadavpur University, an eminent economist, delivered his talk on locational aspects of power plants. The fourth session was presided over by Prof. N. K. Bose, Commissioner of Scheduled Castes & Tribes and a social scientist of distinction. The concluding session was presided over by Prof. E. B. Espenshade from the U. S. A., an eminent scholar of international repute in Geography. An excursion to Massanjore in the Mor Valley provided direct contact with one of the multipurpose projects in the neighbourhood. My grateful thanks are due to the Chairmen of the technical sessions and also to the participants who enlivened the symposium through their papers and discussions. It would not have been possible

for me to have organised this symposium but for the unstinted help extended by the Organising Committee. Particular mention should however be made of the organising talent and dynamism of Prof. Sunil Kumar Munsi, Secretary, Geographical Society of India, without whose collaboration the venture would not have materialised. Dr. S. N. Mukherjee who was the Hony. Treasurer showed an admirable skill in managing with the slender resources placed at his disposal. Another colleague of mine, Sri R. N. Bhattacharyya, gave generously of his valuable time in seeing this brochure through the press. My sincere thanks also go to my students who looked after the reception of guests not only ungrudgingly but with a smile.

May, 1, 1970

Kanangopal Bagchi

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20. Dr. Debkumar Bose, M.A., D.Phil., (Planning of Power Projects, p. 211), Economist, Economic Research Section, Indian Statistical Institute, Calcutta.

POTENTIALS OF ELECTRICITY DEVELOPMENT IN INDIA,
IN THE PERSPECTIVE OF CHANGING ENERGY PICTURE

S. B. Sarkar

Abstract

There are four primary resources on which electricity generation must depend for the time being : water, coal, oil and nuclear fuels. India has abundant resources not only of coal suitable for power generation, the country is also equally rich in water power potentials. But unfortunately, India's proven oil and gas resources are so meagre that they are not even sufficient to meet the ever-increasing requirements of the Road, Rail, Sea and Air transports and import of larger quantities of Petroleum have to be resorted to year after year,



Next to food, it is believed, energy development is the most important criterion for any country to prosper ; and perhaps, more than anything else, industrial progress achieved in a country can be best gauged by the figures of their comparative per capita energy consumption.

Progress of the human race is often marked off into periods based on the types of power employed in productive activity. Firstly, there was the muscle power of man ; this was followed by animal power, wind power, water power, steam power and finally by electricity. Wind, water and steam are still used ; often these are converted into electricity before being put to use. Nuclear energy is being used more and more for

conversion to electricity. The tidal power has also just come into the arena ; and the human race is looking forward to harness stellar radiation and solar energy, in attaining still higher level of prosperity in this world.

It is undoubtedly a fact that modern technology is based on electricity. On this score, India continues to remain almost at the bottom of the list, in per capita generation and consumption of electricity. In 1960, per capita consumption in India was merely 50 KWH against 4700 KWH in the USA and 5800 KWH in Norway. Our aim was to raise per capita generation to 85 KWH by the end of 3rd Plan and 115 KWH by 1970-71 ; and from various considerations to foster industrial development, a target of an installed capacity for 20 million KW has been set for the 4th Plan. Indeed this is not unrealistic, as in attaining increase in national income by 1%, about 10% increase in the national electricity-consumption should be envisaged.

Electricity generation in India was heralded by the setting up of small power plants at the beginning of the century, near metropolitan centres of population, for meeting domestic needs. But with industries coming up and using increasing electrical power, more and larger power plants were set up. These were mostly coal based. In 1920-s, hydel resources began to be exploited with the setting up of the Jog Hydel scheme in Mysore and the Tata Hydel Project near Bombay. Soon after 1947, the hydel sources began to play an increasing role in the nation's power supply net work.

In 1950, i.e. just before launching of the 1st Five Year Plan, total installed capacity for power generation in India was 2.30 million Kilowatts, of which 0.56 million KW was from the Hydel sources, 1.59 million KW from coal and 0.15 million KW from oil. The total electrical energy produced in 1950 was 6575 million KWH which worked out to about 20 units per capita per year. At the same time, the proportion of power generated from hydel sources increased from 24.35% of the total in 1950 to 40.71% in 1965-66. During the

same period, the proportion of Electricity generated with the use of coal declined from 69.13% to 55.16% and that from oil declined from 6.52% to 4.13%. This indicates that the hydel potential was being increasingly exploited. The progress made can be seen from the following :

Table I

Installed power generating capacity in India
(in million kilowatts)

<i>Source</i>	<i>1950</i>	<i>1955</i>	<i>1960-61</i>	<i>1965-66</i>	<i>1971-72 (estimated)</i>
i) Hydel	0.56	0.94	1.92	4.14	8.11
ii) Thermal	1.74	2.48	3.73	6.03	10.67
iii) Nuclear	—	—	—	—	0.64
	2.30	3.42	5.65	10.17	19.42
iv) Energy production in million KWH	6567	10,777	20,123	36,400	75,120
v) Per capita consumption of energy in KWH	19.26	26.94	45.73	72.80	115
vi) Length of transmission & distribution times (KMS)	30,400	58,400	141,400	250,000	—

There are four primary resources on which electricity generation must depend for the time being : water, coal, oil and nuclear fuels. India has not only abundant resources of coal suitable for power generation, the country is also equally rich in water power potentials. But unfortunately, India's proven oil and gas resources are so meagre that they are not even sufficient to meet the ever-increasing requirements

of the Road, Rail, Sea and Air transports and import of larger quantities of Petroleum have to be resorted to year after year.

Hydel Power :

In assessing the hydel potentials of various river basins, India has been divided into 3 well defined geomorphological regions :

- i) The mountain zones of the Himalayas
- ii) Indo-Gangetic plain
- iii) The southern peninsula,

and a break-up of the estimated hydel potentials of these regions has been estimated as follows :

<i>River Basin</i>	<i>Hydel Potential TWH</i>
Ganga basin	25.7
Central Indian Rivers	22.5
West flowing rivers of the Southern India	22.6
East flowing rivers of the Southern India	45.3
Brahmaputra basin	65.6
Indus basin	34.6
	216.4

The Hydro power potential is estimated in aggregate at about 41 million KW at 60% load factor, which corresponds to 216 TWH annual output on a firm basis. The installed capacity in India, in 1966, was only 4.14 million KW (only 10% of the total). Electricity generated from the hydel sources is undoubtedly cheaper ; but less dependable, taking a pessimistic view of the irregular Monscon and providing for maximum storage required. Hydel plant lends itself to considerable flexibility of operation. At low plant factor, it also has great advantage over other methods of generation and is quite suitable for carrying peak loads. It would thus be advisable to exploit hydel resources wherever the geographical

conditions favour, for long term development. However, major hydro-electricity plants take considerable time to investigate and longer time for construction than the conventional thermal or even nuclear power stations. If we consider the above potentials in terms of regions and proportions of hydel potentials already exploited, it will be seen that 30% of the total hydro-potential is in the state of Assam, where less than 1% of the electricity demand is expected, and that so far maximum exploitation of Hydel resources has taken place in the Western and the Southern Regions.

TABLE II

Regions	Hydel potential TWH	%	Hydel potential already exploited %	Percentage of total estimated electricity demand in 1980-81
All India	216.4	100.0	5.5	100.0
Eastern India	14.2	6.5	8.1	26.4
Northern India	36.6	16.9	6.7	9.6
Central India	43.9	20.3	2.9	15.5
Western India	13.6	6.3	15.1	21.5
Southern India	42.6	19.7	11.4	26.1
Assam	65.5	30.3	0.04	0.9

Thermal Power

Though relatively the proportion of power supplied by the thermal sources has gradually gone down in India, yet even today thermal power accounts for as much as 60% of the total generation capacity. The country has abundant resources of low grade non-coking coals almost in the order of 104 thousand million tonnes which are suitable for the purpose of steam raising.

TABLE III

Major resources of non-coking coals in India
suitable for power generation :

<i>Source</i>	<i>Estimated reserves in million tonnes</i>	<i>%</i>
1. Assam (including Nagaland)	3,300	3.2
2. W. Bengal	12,590	12.1
3. Bihar	6,280	6.0
4. Orissa	32,680	31.3
5. Madhya Pradesh	33,600	32.2
6. Maharashtra	5,700	5.5
7. Andhra Pradesh	8,000	7.7
8. Jammu & Kashmir	100	0.1
9. Madras (South Arcot)	2,030	1.9
		100.0

Nevertheless, economics and efficiency of utilisation of high ash coals for thermal generation of electricity calls for special considerations. It has often been thought that geographical location of these reserves is an impediment in developing electricity from coal for countrywide requirements. But the coal map of India is somewhat different today, with newer finds and their exploitation, specially during the last two decades. Eight major States out of sixteen have very sizeable reserves of coal suitable for power generation. It is only the Northern India and the West coast that cannot be best served by electricity from coal, within the scopes of available regional grids, as it is uneconomic to haul and transport this coal over long distances, and therefore rendering the location of the steam power stations rather important.

On an average, 70% of the cost of generation of electricity in India is contributed by the delivered cost of coal. It is imperative that the future power plants be located at or near the pit-heads. Fortunately the modern design of pulverised fuel fired boilers are capable of ensuring high efficiency of

burning poor quality coals. Moreover, technological progress in the transmission techniques has also brought about an increasing trend for setting up of large thermal stations near the coal-fields. This has become practicable as, firstly, the galloping demand of power makes large-scale plants feasible and secondly, modern high tension techniques have rendered the long distance transmission cheaper, by drastically cutting down the wastages in transmission.

Taking the advantages, we have thermal power stations of almost 500 MW capacity today as against power houses of 20 or 30 MW which were common in 1947. It appears therefore that the increasing generating capacity of thermal power will largely be based on coal, except in the regions which are possessing some natural gas resources. With the abundant indigeneous resources of low rank as well as high ash coal suitable for power generation in one hand, and increasing mechanisation in coal mining on the other (including the future possibilities of pipeline transportation of coal), application of larger and larger units for thermal power generation appears to have considerable prospects in the country.

Apart from the inferior raw coal, substantial quantities of washery middling and rejects are also being produced. The middlings or byproduct coals from the washeries are rather high in ash, 35-40% which can be satisfactorily made use of, only in the generation of thermal electricity. Indeed, economics of coal washing for the Iron & Steel industry will depend to a great extent on the gainful utilisation of these byproduct coals. It has been estimated that by the end of 4th Plan alone, about 24-25 million tonnes of coking and blendable coals will have to be washed; and something of the order of 7 to 8 million tonnes of byproduct fuels will be seeking for an outlet, depending on the quality of coals to be treated in the washeries.

India is equipped today to build efficient Power units of 110 MW and above, and it is most unlikely that additional steam plants, envisaged during 4th and 5th Five Year Plans, will be any smaller than that.

The generating capacity from the thermal resources (including oil) totalled upto 6.03 million KW at the end of 3rd Five Year Plan ; with this, another 5.71 million KW is expected to be added, during the 4th Plan.

Irrespective of limited oil resources in the country, oil-based thermal power plants had to be set up close to the refineries at Barauni and Gauhati for different reasons, and Natural Gas fired stations at Dhubaran and Namrup.

Nuclear power

It is a matter of pride that India, on its own has been able to develop atom for peace to such an extent. Although no actual nuclear power was generated during the 3rd Plan, an atomic power station of 380 MW was being installed at Tarapur, Maharashtra, to be completed soon. The Second 400 MW nuclear station will come up at Rana Pratap Sagar by the end of the 4th Plan ; and there is a similar proposal for Kalpakkam near Madras in the 5th Plan.

India's reserves for nuclear resources are to be found in two forms : Uranium and Thorium. The Uranium can be used directly in the reactors, but the Thorium cannot be directly used as fuel in its natural form. A number of deposits of Uranium has been located in Bihar, Rajasthan and Madras. It has been estimated that total amount of Uranium, definitely contained in these deposits, is much above 2000 tonnes, which is capable of yielding, in the Candu type reactors, some, 10,000 MW-days per tonne, sufficient to provide nearly 1 million KW of nuclear power for 20 years, or the full life of a reactor at 75% load factor. The Monazites of Kerala probably contain an additional 30 thousand tonnes of Uranium.

In respect of Thorium reserves, India is very fortunate. There are some 200 thousand tonnes of Thorium in Kerala, and still larger deposit recently discovered by the Atomic Minerals Division, at the Ranchi Plateau.

Relative costs :

Past trend in the consumption of coal for power generation reveals that on an average, 2900 tonnes of coal is required per MW of installed capacity annually, while corresponding figure for the oil fired power stations is about 1400 tonnes. The national average of unit-consumption of coal per unit of electricity generated has gradually fallen from 2.2 lbs. per KWH in 1950 to about 1.6 lbs. in 1967, with the rapid introduction of more modern and larger power plants and an effective economy drive initiated by the Coal Board and the Central Water & Power Commission. There will however be a further decrease in the requirement of coal or oil, per unit generated, in the coming years by means of increased fuel efficiency attained from improved operations in more modern and larger Power plants.

The Energy Survey Committee, set up by the Government of India in 1963, made a comparative study of the investment per kilowatt and the cost of generation per kilowatt hour in typical hydel, thermal and nuclear stations in the country. Their estimate of investment per KW was Rs. 1,475 for storage hydel designed for 60 per cent plant factor, Rs. 1,343 for thermal plant and Rs. 2,222 for nuclear plant. With 60 percent plant factor and an assumed cost of Rs. 24.5 per tonne of coal of 4400 kcal/Kg, the cost per kilowatt hour worked out to 2.9 paise for hydel, 4.6 paise for coal-based thermal and 5.8 paise for nuclear stations. Nuclear stations will generally operate at a higher plant factor, and for a factor of 75 per cent, the overall cost gets reduced to about 4.7 paise. This no doubt compares well with coal-based stations located far away from the collieries.

In the light of above, major problems that should be considered in framing a sound electricity policy in India are :

- 1) Assessment of rate of growth of electricity-demand.
- 2) Choice of different methods of power generation, e.g. Hydel, Thermal and Nuclear; and their location in relation to economics and availability of resources.
- 3) Attainment of increasing efficiency of thermal power generation.
- 4) Problems of laying a National Grid.
- 5) Standardization of Plant-size in relation to fuel-availability.

So far as siting of hydel power stations are concerned, we cannot choose any and every place except those which lend to generation of hydro-electricity. As regards nuclear power, we can choose any site paying due heed to safety and load considerations. But while looking at the comparative cost of installation and power generation, it will be worthwhile locating the nuclear stations in India, furthest from the coal belts; and coal-fired power stations at or near the collieries or coal washeries. While looking back at the projected installed capacity for the conventional thermal stations on coal and oil, at Table I, it may be concluded that amongst various resources for electricity development in the country, coal will continue to share the major burden, in the years ahead. However, the Hydel Power Potentials can effectively serve to redress the lack of balance in the coal resources.

The development of generating capacity could not always be linked to the demand. There is also the instability caused by the excessive dependence, in certain areas, on hydel power and consequently on the vagaries of the monsoons. To overcome these problems, a National Power Grid can be the only solution. By linking up Thermal, Hydel and Nuclear power plants in all parts of the country, it will lend stability to the system of power supply. It will also bridge the gulf between the power deficit and surplus areas,

thus providing for the most sensible utilisation of installed capacity and the national resources.

As a major step towards the goal of coordinated development of the existing power-systems, the Fourth Plan envisages interconnected operation at extra high voltages. The emphasis will however be on the interconnection of various power systems and inter-state transmission lines so as to evolve the regional grids during the Fourth Plan. But until a true National Grid at the highest transmission voltage and capacity can be laid, regional imbalances and that in the development of Power from different sources will remain and it *will* not be possible to take the fullest economic advantages in the electricity generation and usages. For instance, although the Brahmaputra Basin holds the maximum of unexploited hydel potential, harnessing the same will remain a dream until a National Grid has come into operation. The same is true when it is thought of transmitting cheap electricity from the coal belts to the distant corners of the country.

Fossil fuels in any case represent only a finite reserve, life time of which could be measured say in hundreds of years but not in thousands. Therefore, a time may soon come when nuclear power will tend to reduce our dependence on fossil fuel reserves for a time. If the present obstacles in the development of fusion power could be removed, we could meet our future energy requirements for a time with nuclear energy. However, control of fusion process is still a challenge to the Nuclear Scientists and Engineers.

As the next alternative, Scientists are also taking now a close look at the solar power as an abundant source that could free man from his dependence on fire, if successful. Recently the space programme initiated by the United States of America and Russia have indicated that solar energy could be directly converted. In fact, the major success of the space-craft and orbiting satellites came with the support of power from solar

cells. At the present moment, the economics of harnessing solar power may be questionable, but it is to be remembered that for this, we are looking ahead by a hundred years or more.

Read at the Symposium (26th to 29th November, 1968) on Hydel & Thermal Power and its Geographical implications in Developing Countries (sponsored by the University Grants Commission on the occasion of the International Geographical Congress, 1968).

DEVELOPMENT OF POWER SUPPLY IN THE EASTERN REGION
(BIHAR, ORISSA AND WEST BENGAL)

N. K. De Sirkar

Abstract

At the time of our independence the state development of power supply in this country was insignificant. The installed capacity of the whole country was just about one million KW. West Bengals' installed capacity was 3,49,000 KW. of which more than 300,000 KW. was in Calcutta and surrounding region. In Bihar it was about 32,000 KW. of which 6000 KW. was at Patna. The main bulk of generation was in the Jharia coal field region. The installations in Orissa was about 1500 KW.

After independence the development was significant, and by 1967 the total installed capacity in the country was about 10 million KW. of which the shares of West Bengal, Bihar and Orissa were 1.3 million, 1.1 million and 0.6 million KW. respectively. In the field of Power Supply in Eastern Region, D.V.C. first came into existence, and the achievement of the D.V.C. in the field of flood control and irrigation has also been very important. The D.V.C. now supplies about 100,000 KW. of power to Calcutta region and also supplies power to three major steel works in the country.

The West Bengal State Electricity Board has also developed power supply from the

Hydro-electric Station located at Jaldhaka and the Thermal Power Station at Bandel. New construction of a Thermal Station is now being made at Santaldih area for supply of power to Calcutta industrial belt.

The Bihar State Electricity Board is also advanced developing power stations at Baruni and Patratu. The Orissa Board starting almost from nothing has built up a capacity of more than 500,000 KW.

In the Eastern Region, the D.V.C. Power system only generates power in large scale and sells in bulk to the State Electricity Boards, distributing licences to large industries. The State Electricity Boards now in addition to generating and transmitting power in bulk distribute energy to small industries or towns and rural areas. All the major power systems in the region were interconnected with each other. The D.V.C. system was interconnected with Rihand Hydro-electric Station of Uttar Pradesh so that in the periods of scarcity, the Industrial Regions of Bihar and West Bengal were fed by Rihand System. Interconnection of the Orissa system with that of West Bengal, Bihar and D.V.C. is at present rather weak. However this process of interchange has two sided benefit. The shortage area gets a relief and the industrial production is maintained, and the system which renders assistance is benefited because they earn additional revenue.

Plans are now under execution for inter-connecting Orissa system with West Bengal, Bihar and D.V.C. systems. The coordinated operation will provide the consumer with most

efficient service at the lowest possible rates. On the basis of geographical distribution of coal, both Electricity Boards of Bihar and West Bengal will try to install their large scale generating stations in the area as the D.V.C. Each of the component units is accountable individually for its performance and there will be limitations to the extent of co-ordinated operation for best overall economy that could be effected.

There are two alternative solutions to this problem. First and less satisfactory one is to co-ordinate planning of the generating capacity and large scale transmission for the entire eastern region on the assumption that the whole region is one power supply area. A still better arrangement would be to entrust generation and large scale transmission in the eastern region to a single generating organisation. This organisation could be a partnership of the three State Governments in the region. The Central Government should also be a partner in the scheme since fairly large volume of transmissions will take place across the boundaries of the State belonging to this region.

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At the time of our independence the state of development of power supply in this country was ridiculously insignificant. The installed capacity in the whole country was just about one million KW. West Bengal's installed capacity was 3,49,000 KW of which more than 300,000 KW was in Calcutta and surrounding region. In Bihar, the installed capacity was about 32,000 KW of which 6000 KW was at Patna. The main bulk

of generation was in the Jharia coal field region. The installations in Orissa was about 1500 KW.

During 20 years of independence, our achievement in developing power supply in this region is of some significance, even though we are not content with our own achievement. At the end of the year 1967, total installed capacity in the country was about 10 million KW, of which the shares of West Bengal, Bihar and Orissa were 1.3 million, 1.1 million and 0.6 million KW.

In the field of power supply in the Eastern Region an important factor which came into existence even during the first year of independence was the Damodar Valley Corporation. The DVC was created as an autonomous organisation by an Act of Parliament in which the two State Governments of Bihar and West Bengal joined the Central Government to achieve co-ordinated integrated development of the water shed area of the turbulent river Damodar. The DVC was charged with the task of controlling floods in this interstate river, irrigating agricultural fields wherever possible, generating power for supply to industry and develop the area of the Valley in all respects. The achievement of the DVC in the field of Flood Control and Irrigation has been very important, but they are not spectacular. The very big floods which the DVC Flood Control Dams checked and moderated to harmless flows did not hit the headlines. It is difficult to readily realise the value of devastation not perpetrated. The total amount of food being in short supply in the country, the achievement in the field of irrigation also goes unnoticed. In the case of power supply, however, the story is very different. The power supply industry by its very nature is an ever growing industry. The commitment for power supply in any area continues to grow at a slow or rapid rate depending on whether it is industrial or rural area, but the growth never stops. It is difficult to foresee if ever a saturation point will be reached. The DVC's task was to develop a power supply system cutting across the political boundary of West Bengal and Bihar.

Starting with an initial installation of 150,000 KW at Bokaro and 4000 KW at Talaiya in 1953, the DVC has built its system with an installed capacity of 1061,000 KW which is almost equal to the total installation in the whole country at the time of independence. The Power System of the DVC stretches from Patna and Sonenagar in the west to Calcutta in the east, a stretch of 450 miles. The System now supplies about 100,000 KW of power to Calcutta region and also supplies power to three major Steel Works in the country, namely, Jamshedpur, Burnpur and Durgapur. About 80% of coal produced in the country depends on DVC Power System.

The West Bengal State Electricity Board has also developed power supply in areas not served by the DVC during this period. The Hydro Electric Station at Jaldhaka and the Thermal Power Station at Bandel are important achievements. The State Board is now constructing a major Thermal Power Station at Santaldih area for supply of power to Calcutta industrial belt. Power will be transmitted over 400 KV transmission lines from Santaldih. In West Bengal, Durgapur Projects Ltd. also has a large Power Station in the Durgapur area which also feeds into the West Bengal Board's Power System. The West Bengal Board has installed many other comparatively small diesel generating stations in many locations where power cannot economically reach through a high tension transmission system. The total installed capacity of different installations owned by West Bengal State Electricity Board is 385,000 KW. In addition to this, Durgapur Industries Board has installation of 285,000 KW.

The Bihar State Electricity Board also is developing a large Power System. The major Power Stations now are Barauni with three units of 15,000 KW and two units of 50,000 KW and Patratu Thermal Power Station with four units of 50,000 KW and two units of 100,000 KW. There are also a large number of diesel and small steam generating stations in many

towns in the Bihar State. The Bihar State Electricity Board has done considerable work in distributing DVC power not only in the area of the DVC, but also at such distant places as Bhagalpur and Sultangunj.

The Orissa State Electricity Board starting almost from nothing has built up a capacity of more than 500, 000 KW.

In the Eastern Region consisting of Bihar, Orissa and West Bengal, the DVC Power System only generates power in large scale and sells in bulk to the State Electricity Boards, distributing licensees and large industries. They do not distribute power to small industries or towns and rural areas. All the three State Electricity Boards now in addition to generating and transmitting power in bulk distribute energy to small industries, towns and in rural areas. The work of distribution of energy in retail, although less glamorous, is painstaking and some time uneconomical work. Somebody could suggest that large scale generation and transmission is a kind of business which is quite different from retail distribution of energy, and the two should be handled by two separate organisations.

The development of power supply in this region had a share of usual troubles. Initially when large scale power generation was pioneered by the DVC by installation of three 50,000 KW units at Bokaro, the largest thermal units in the country at that time, they had to face the criticism of being too extravagant in planning. Gradually as the demand for power increased supply was very soon overtaken by demand. The Power Supply organisations usually did foresee the demand sufficiently ahead of time and planned to augment their installation of generating capacity. Unfortunately due to pecuniary difficulties which the country was having all the past years, they had to do with very much less than that was necessary for their respective areas. As a result, occasionally grievous shortage of power supply occurred in this heavily industrial region of the country. This, however, had one / indirect beneficial effect. Power authorities were usually very

conscientious in their attempt to meet the demand for power supply in their respective regions. In order to do so, they had to call upon assistance from the neighbouring systems, which perhaps, they would have avoided if each was affluent and self contained. All the major power systems in the region in the process became interconnected with each other. The DVC Power System was interconnected with Rihand Hydro Electric Station of Uttar Pradesh by a 100 mile transmission line from its western-most end. During the period of scarcity of 1962 and 1963, the starving industrial regions of Bihar and West Bengal were fed from Rihand Hydro Electric System and this eventuality was never thought of by planners either in Rihand or in DVC. When power shortage occurred in Rihand supply area in 1966 to 1968 due to drought the DVC system came to their assistance in big way. Interconnection of the Orissa System with that of West Bengal, Bihar and DVC is at present rather weak. Even then during the periods of shortage valuable assistance is obtained from Orissa System by transferring a part of the DVC load on the system. It must be remembered that this process of interchange have a two sided benefit. The area in which the shortage occurs gets relief. In other words, industrial production is maintained. On the other hand, the system which renders assistance is also benefited, because they also earn additional revenue which they would not have ordinarily from their own area. There occurs a net gain to the national economy through better use of investment.

At present, Power System of West Bengal State Electricity Board, Bihar and the DVC have been effectively interconnected and the interconnections are being further strengthened and developed. Plans are also under execution for interconnecting Orissa System with the West Bengal, Bihar and DVC Systems. The Eastern Regional Electricity Board which was formed in March, 1964 to co-ordinate the activities of power development in this region, periodically discusses the policy matters regarding interchange of power between these systems. A number of technical committees consisting of the

engineers of all the organisations in the eastern region regularly discuss the details of co-ordinated operation and other problems. For the time being a workable arrangement has been achieved in this region for co-ordinated operation of the four major Power Systems and also for interconnection with the Rihand System.

It can now be said that power supply industry in the Eastern Region has come of age. As mentioned before, all the systems are interconnected with each other and interconnections are being developed. Each system is preparing plans to meet the growing demands in their respective service areas. Although very effective co-ordination and co-operation exist among the interconnected systems, the actual exchange takes place only to get over the difficulties created due to short or comparatively long term shortages in different areas. The shortage occurs for various reasons like delay in completion of planned projects, drought causing shortage of water in the reservoirs or emergency breakdown of machines and transmission lines. Otherwise under the present system of operation decided upon, each system is expected to be self-sufficient in the matter of firm capacity as compared to demands on their systems.

It is time to consider whether we are moving in right direction and whether we are arranging to provide the consumer with most economical and most efficient service. It must be borne in mind that power supply industry is a capital intensive industry which also being essential service is expected to provide supply at lowest possible rates consistent with the economic operation. Geographical distribution of coal deposit in this area is such that most of the usable coal and middlings are produced in the statutory area of the DVC or very close to it. There is, however, a large deposit of coal in Orissa near Talcher. On the basis of this geographical distribution, it is only natural that both the State Electricity Boards of Bihar and West Bengal will try to install their large scale generating stations in the same area as the DVC. The

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DVC have permitted the State Electricity Boards to instal generating stations inside the Valley for supply outside to statutory limits. High voltage transmission lines will be taken out from those stations to different load centres in Bihar and West Bengal. It may be repeated here that each system is now expected to be self-sufficient not only in respect of generation but also in respect of transmission of power as a permanent measure. Marginal transfers will take place between the systems and also wheeling of energy over the transmission system of one of the agencies on behalf of the other also will be common. In spite of this co-operation and co-ordination, duplication of investment will occur in the transmission system and also in generating capacity. Since each of the component units is accountable individually for its performance, there will be limitations to the extent of co-ordinated operation for best overall economy that could be effected.

There are two alternative solutions to this problem. The first and less satisfactory one is to co-ordinate planning of generating capacity and large scale transmission for the entire eastern region on the assumption that the whole region is one power supply area. All the generating units and the high tension transmission system in this area should be placed under a single operating control, the power would be supplied through distribution agencies of the State Electricity Boards for distribution at tariffs which should be uniform over large areas not necessarily uniform over the whole region. The performance of the bulk generation and the transmission grid could be assessed for the region as a whole. Under this arrangement suggested, each authority will retain financial ownership over the generating stations and certain part of the transmission grid and the employees in the installations owned by them. This proposal has its drawbacks. A still better arrangement would be to entrust generation and large scale transmission in the Eastern Region to a single generating organisation like the central Generating Board, of the United Kingdom. This organisation could be

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a partnership of the three State Governments in the region. The Central Government should also be a partner in the scheme since fairly large volume of transactions will take place across the boundaries of the States belonging to this region. In spite of the temporary difficulties faced by the DVC, the working of the DVC has demonstrated that the co-operation suggested above is not unworkable. In conclusion I will remind that almost 80% of the coal produced in the country is mined in this region. It contains three of our four major Steel Works existing and the fifth one under construction and also the only copper producing unit in the country. On the basis of any sensible economic plan, development of industry in this region should be at a more rapid phase than the other parts of the country in the national interest unless we want to forego the economic advantages of development which have already taken place due to political considerations. It will bear repetition to say that stability of power supply in the Eastern Region is vital to the national economy and more important than any other part of the country. A very stable and economic power supply is the back-bone of industrial development and it could be done most effectively by a single generating organisation serving the interest of the three States.

COST OF POWER SUPPLY AND LEVELS OF UTILISATION

Dr. A. N. Bose

Abstract

Lack of rural electrification in West Bengal has assumed a new dimension today in the background of the following two basic revolutions that have occurred in the structure of West Bengal economy during the three Plan periods : (1) in the structural composition of the State income measured at constant price of 1951-52, the domination of agriculture has been replaced by that of industry sector, and (2) in the structural composition of the manufacturing industry, the domination of jute industry has been replaced by that of the engineering industry.

These two revolutions have not only created the objective basis for materialising in practice the long-felt need of industrialisation of agriculture, but have also laid bare the fact that unless the latter is done, the two revolutions will not be able to consummate themselves and that will get expressed in recessions.

Again, industrialisation of agriculture by substantially increasing the load factor in rural electricity supply will lead to lowering the cost of production (and distribution) of power and also to lowering the investment needed for generating power, and these in their turn will

further accelerate rural electrification and agricultural modernisation. To indicate the whole process there will be a need for cheaper power supply in rural areas.



1. The purpose of presenting this preliminary draft note is :

- (i) to emphasise the already known fact as to how a fuller utilisation of capacity reduces substantially the cost of production per unit as well as the investment need for supplying a given quantum of goods, including power,
- (ii) to represent the nature of structural change that has occurred in the economy of West Bengal during the plan period and how it has laid one aspect of the material basis for industrialising the country-side by industrialising agriculture, which need be supplemented by adequate power availability.

2. During the period 1959-60 to 1967-68, the installed power generating capacity in West Bengal increased from 608.1 M.W. to 1498.4 M.W. denoting an increase by 146% during this 18 year period (Table 1). It is however, interesting to note that the entire volume of power generated in 1967-68 could have been generated without any increase in generating capacity during this period i.e. with the capacity already installed in 1959-60. However, it would have required utilisation of 91.3% of generating capacity, which may be considered beyond the possibility of achievement. Actually achieved level of capacity utilisation, however, varied between 32% to 41% in West Bengal as a whole, although the Calcutta Electric Supply Corporation did utilise, inspite of a not very wide-spread multiple-shift operation in manufacturing units, 60 to 69% of the generating capacity. And this means that the only other system of public utility, viz. West Bengal State

Electricity Board, could use only about 4% of its installed capacity. For example in 1962-63, C.E.S.C. actually generated 2328 million kwh compared to 3636 million kwh possible (i.e. 64% of capacity) while the W.B.S.E.B. generated only 150 million kwh compared to 3796 million kwh possible (i.e. only 3.9% of capacity). The overall rate of capacity utilisation, taking both the systems together was 33.3%. Even if 50% of the industrial units would have had used the night shift for production, the level of capacity utilisation in the Calcutta area could have been substantially increased. And so a level of capacity utilisation in the vicinity of 70 to 75% is certainly not beyond the reach of realisation and this would have had made possible the generation of 4820 million kwh (which was the actual generation in West Bengal, in 1966-67) not with a capacity of 1498 MW (as was actually done in 1966-67) but with only a capacity of 734 MW.

3. How a change in the level of capacity used may change the fixed cost of production of power may be clear from a hypothetical example. Assuming that capital cost for installing generating capacity to be Rs. 1700 per KW, the total fixed capital cost for a 150 MW station will be Rs. 25.5 crores. If the capital cost is to be recovered by the annuity method in 15 years at 6% rate of interest and if capacity is to be kept 15% higher than the peak load, then fixed cost per unit of power generation will vary from 2.55 paisa at 90% load factor (which is the level of capacity used with reference to peak load) to 11.49 paisa at 20% load factor. Pattern of change in the fixed cost per unit of power generation at different levels of rate of interest and at different load factors may be clear from table No. 3.

4. It may be mentioned here that once upon a time one of the major attraction for locating industry in Calcutta area was the availability of cheap, abundant power. During the planning period, W. Bengal has lost the lead she once had

over other states. In 1951, West Bengal claimed only 7.4% of the total population of India, but her share of power generating capacity was more than four times higher : 29.8%. In 1963-64, however, while her share of all India population increased to 8%, her share of all India power generating capacity declined to mere 13.8%. And the gap between the per capita consumption of power in West Bengal with that of India is sharply going down ; while in 1963-64 the per capita power consumption in West Bengal was higher by 1.96 times [W. Bengal 108 : units, compared to 55 units for India], the estimate for 1968-69 show the ratio has declined to 1.55 [West Bengal : 185 units, India : 119 units] denoting a decline by 21% in 5 years, 1963-64 to 1968-69. And electricity tariff now in many areas outside West Bengal is not only substantially lower than that charged by the State Electricity Board but they are even lower than that of even the C.E.S.C. system. For example, the large units even in the Calcutta area are to pay 52-58% higher tariff compared to that in the hydro-electricity areas of Maharashtra. The details may be clear from the table No. 4.

5. Along with relatively high tariff rate and lower share of generating capacity, West Bengal has now also become one of the most backward states so far as rural electrification and modernisation of agriculture are concerned. Table No. 5 giving the percentage of villages electrified in different States clearly shows that in 1965-66, the relatively highly industrialised State of West Bengal should be classified, from the point of view of rural electrification, with such industrially backward states as Nagaland, M.P., Orissa, Assam or Rajasthan. Compared to the all India percentage of villages electrified, which was more than 9%, the states mentioned above could not electrify even 4% of their villages—the exact percentage for West Bengal was even lower : 3.12%. In contrast, 70% of the Madras villages, 25% of the Punjab and Hariyana villages had been electrified.

6. A similar picture emerges, so far as West Bengal is

concerned, if we study the number of tubewells energised for irrigation purposes in the different states. Compared to only 431 pumps energised in West Bengal by the end of the third plan, 57 thousand have been energised in Andhra and as many as 256 thousand have been energised in Madras (table No. 5). In this respect also, West Bengal belongs to that group of states which include Nagaland, Jammu and Kashmir, Assam. Again, while electricity consumed in India as whole for irrigation and agricultural dewatering increased from 733 million kwh in 1960-61 to 1397 million in 1964-65, i.e. almost by two fold, the corresponding increase in West Bengal for irrigation purposes was nil. It remained static at the level of 2.6 million kwh (table No. 6). While irrigation claimed only 0.07% of total power consumed in West Bengal, the corresponding proportion for India as a whole was 5.8% in 1964-65; and while for India this share has been continuously increasing (it was 3.9% in 1956, 5.2% in 1960-61 and 5.8% in 1964-65) that for West Bengal continuously declined up to 1964-66 (Table No. 6). And despite a sharp increase in the volume of power consumed in irrigation in West Bengal during the latter years, it constituted even in 1967-68 less than 0.5% of total consumption.

7. It may appear from above that for restoring the lead West Bengal has lost in generating capacity and tariff rate, and, what is more important, for playing an adequate role in the development of agriculture, a huge capacity creation will be required and it may well be beyond the possibility of actual realisation. In the sphere of capacity creation also, the role load factor plays in determining the volume of capacity required may be clear from table No. 7 giving the capacity required at different levels of load factor for supplying about five times more power (i.e. 24,000 million kwh) than was generated in West Bengal in 1966-67. It may be clear from this table that if the load factor remains at 40% level, the capacity may have to be increased by (7020-1435) or 5585 MW. i.e. by about 4 times of what existed in 1966-67. But if it is possible to achieve a load factor of even 70%,

then new capacity creation need be only 2576 MW. i.e. an increase of less than two times of the 1966-67 level. It may be mentioned that an increase in the load factor from 40% to 70% would mean a reduction in additional capital investment requirement for generating 24000 million kwh from Rs. 950 million to Rs. 438 million i.e. by less than half. Again, if a ten year programme is taken for this capacity creation, it would involve a rate of increase of 17.2% per annum (compound) from the 1966-67 level at the 40% load factor. It may be mentioned that the latter rate of growth is lower than the actually achieved rate during 1959-60 to 1966-67 in West Bengal which was 13%. Thus, if a 70% load factor can be achieved, then by increasing capacity at the rate of 10.8%, it will be possible to increase power supply at the rate of 17.9% per annum.

8. The main reason for a low load factor in West Bengal, particularly in areas outside the Calcutta area, lies in the utter lack of modernisation of agriculture which still now is completely dependent on the vagaries of nature. The extent of the dependence on nature may be clear from the wide fluctuation in the volume of agricultural production during 1960-61 to 1967-68 as measured by income generated at the constant price of 1951-52 (table No. 8). The fluctuations have been so wide that the average annual production for the last eight years, 1960 to 1968 was less than that of the initial year 1960-61, which was not the peak production year, denoting an average decline or stagnation in agricultural productivity in West Bengal. However, a steep price rise during this period kept the money income from agriculture at current price at a relatively high level; and that is why in spite of average decline in production by 3%, there has been an increase in money income by 44% and the difference between the income generated in agriculture and measured at current price, and that measured at constant price comes to nearly Rs. 14,000 million during this 8 year period or an average of Rs. 1,750 million per year. That this huge sum must have accrued mostly to those small minority among the agriculturists, who



were net-sellers of agricultural products and the traders, and that this sum was not used for modernisation of agriculture, for freeing it from the vagaries of nature go to explain the present condition of agricultural backwardness of West Bengal. It is instructive to note that while average annual income during these eight years at current price was higher by 47% compared to that at constant price in case of agriculture, the same was only 8% higher in case of *industry*. Further, during the eight year period, 1952-53 to 1960-61 index No. of wholesale prices in India increased by 23.8% in agricultural commodities and by 23.9% in manufactured commodities (i.e. the rates of increase were more or less same); during the latter eight years, 1960-61 to 1968-69, the same for agriculture increased by 75% compared to only 36% increase in industry (Table No. 9).

9. Relatively higher price rise in agriculture did not get reflected in attempts to modernise agriculture for achieving a sustained increase in agricultural productivity during this period at least in West Bengal which would have had created the basis for modernising rural areas with centres of industrial growth based on demand for industrial goods and services from modernised agricultural sector with the consequent need for and demand of power. The "price incentive" in agriculture could not lead to the expected result of agricultural modernisation because of in-built barriers in the present institutional set up in agriculture to which, it seems, the present pattern of agricultural backwardness is more profitable than the socially desired pattern of agricultural modernisation. And this lack of agricultural modernisation is not only keeping the supply position of food and industrial raw material in a precarious condition, it is preventing the full utilisation of whatever industrial capacity, including the capacity for power generation, which we already have, by preventing an expansion of demand for industrial goods and power from by far the biggest economic sector in our country—the agriculture.

Structural Change in the West Bengal Economy

10. It is this backwardness of agriculture which has in a way contributed to the first basic change in the economic structure of West Bengal that has occurred during the plan period. At the beginning of the plan period in 1951-52, income generated by the industry, including small establishments, in West Bengal was only 36.7% of that generated by agriculture. This dominance of agriculture and the corresponding subsidiary position of industry were reversed by the end of the third plan period. In 1965-66, industrial income (at 1951-52 constant price) was *higher* by 5.7% than the corresponding income from agriculture. This is a fundamental structural change in the income composition of the State.

11. The second structural change concerns the composition of the manufacturing sector itself. Long dominated by the backward agro-based industry—jute—West Bengal industry had by 1959 transformed itself into an engineering based industrial structure and the subsequent 9 years had further strengthened the dominating position of engineering industry in the West Bengal economy.

12. But these fundamental changes in the economic structure are not being able to consummate themselves, so to say, and the end result has so far been not further changes in the economic structure by utilising industrial goods for modernising agriculture but recession. Unlike in the previous period, when our entire economy, including industry, was suffering from lack of development, lack of capacity, lack of capital, to-day our industry sector has started suffering from lack of demand. It has been estimated that more than two-third of the existing productive capacity in our industry, including engineering and power supply industry, is lying idle mainly because there is no demand for their products. This is a peculiar situation in a developing country, which is supposed to be suffering mainly from lack of capital along with 'population explosion', and it constitutes the third aspect of the structural change.

13. However, the contradiction between the excess capacity in industry and lack of capacity in agriculture can be solved in the technological, input-output level if the excess capacity in industry can be used to generate new capacity in agriculture. This is not only the material basis for having our backward agriculture modernised, industrialised; unless the latter is done the huge capacity created in our industry sector including power will not be used. The basic choice before our state economy to-day is either to face a secular stagnation or to have a complete industrialisation of agriculture, one aspect of the material pre-condition for which has already been created. Carrying forward that which already exists for a fuller development of the material pre-condition in its totality, it is now necessary for the power industry to go ahead with rural power supply so that the process of agricultural modernisation may not have to come to a halt due to lack of power.

14. This development of the material pre-condition in itself can not guarantee that such a transformation will take place in real life. This will necessitate the development of complementary pre-condition enabling the substitution of the presently dominant socio-economic institutions interested in the continuation of the status quo by those whose interests lie in having such a transformation, material basis for which now exists, achieved in actual reality. The task of capacity creation in power industry, therefore, will have to take into account the complementary task of re-designing the total environmental and institutional setup of the present society both to economise on the requirement of the capacity and to use economically the capacity which may be developed.

Table 1

*Installed Capacity, Generation and Estimated Load Factor
in West Bengal, 1959-60 to 1966-67*

Year	Installed capacity (in thousand kw)	Generation (million kwh)	% of generating capacity used
1959-60	608.1	2,004.3	37.8%
1960-61	636.7	2,282.2	40.9%
1961-62	697.7	2,293.3	37.5%
1962-63	848.8	2,477.9	33.3%
1963-64	835.9	2,726.0	37.2%
1964-65	975.4	4,037.9	47.2%
1965-66	1,243.0	4,080.4	37.5%
1966-67	1,498.4	4,819.7	36.7%
1967-68	1,498.4	4,861.3	37.0%
% increase (1959-68)	146.4%	141.3%	

Source : Economic Review, 1967-68
Government of West Bengal, P. 70

* assuming a peak load of 90% of installed capacity

Table 2

*Load Factor in the Calcutta Electric Supply System
1960-1965*

Year	1960	1961	1962	1963	1964	1965
Load factor	60%	62%	62%	69%	68%	65%

Source : C. E. S. C.

Table 3

Estimated fixed cost per unit of Power Generation and different levels of Load Factor and at different levels of rate of interest*

Load Factor**	Paisa per unit			
	Cost per unit at the rate of interest of			
	5%	6%	7%	8%
100%	2.15	2.30	2.45	2.61
90%	2.39	2.55	2.72	2.90
85%	2.53	2.70	2.88	3.07
80%	2.69	2.87	3.06	3.26
70%	3.06	3.28	3.50	3.72
60%	3.21	3.43	3.66	3.89
50%	4.30	4.60	4.90	5.21
40%	5.38	5.74	6.13	6.52
30%	7.17	7.66	8.17	8.69
30%	10.75	11.49	12.25	13.03
10%	21.50	22.98	25.50	26.07
5%	43.00	45.96	51.00	52.14
% change in the cost for a change in the L.F. from 70% to 30%	+234%	+234%	+234%	+234%

*assuming capital cost of Rs. 1700 per kw.

**Actual generation in a year $\times 100$
 $\frac{\text{peak load} \times 8760 \text{ (i.e. no. of hours in a year)}}{\text{peak load} \times 8760 \text{ (i.e. no. of hours in a year)}} = \text{load factor}$

Table 4

*Average Rate of Electricity Tariff
As on 1st August, 1967**

(Paise per Unit)

	For Small <i>industry</i> (10 kw 20% L.F. 1460 kwh/ month)	For medium <i>industry</i> (50 kw 30% L.F. 10,350 kwh/month)	For large <i>industry</i> (250 kw 49% L.F. 73,000 kwh/ month)	For very large <i>indus- try</i> (1000 kw 50% L.F. 365,000 kwh/ month)
1. West Bengal				
a) State Elec- tricity Board	19.50	17.80	41.01	13.04
b) Calcutta Electricity Supply Corp.	14.00	12.87	13.05	12.11
2. Maharashtra				
a) Hydro Area	16.11	16.77	8.55	7.66
b) Steam Area			13.51	11.94
3. Madras				
a) Thermal			18.69	16.98
b) Rest	16.56	15.43	14.61	12.88
4. Gujarat	14.64	13.75	14.50	12.69
5. Bihar	19.00	18.66	11.83	10.33
6. Mysore	13.00	12.45	8.53	7.46
7. Punjab	12.62	11.04	9.14	7.91

* Memorandum submitted by the
Bharat Chamber of Commerce

Table 5

*Percentage of Villages Electrified and No. of Pumps
Energised in Different States of India Till
1965-66*

Name of the States	No. of inhabited villages 1961	No. of electrified villages 1956-66	% of vill. electrified to total no. of inhab. villages	No. of pumps energised
1. Andhra Pradesh	27,084	5,437	20.07	57,225
2. Assam	25,702	75	0.29	—
3. Bihar	67,665	3,870	5.72	10,660
4. Gujarat	18,584	1,751	9.42	17,154
5. Jammu & Kashmir	6,559	632	9.64	65
6. Madhya Pradesh	70,144	1,213	1.72	4,075
7. Madras	14,124	9,869	69.87	2,56,366
8. Maharastra	35,851	4,618	12.88	45,145
9. Mysore	26,377	4,136	15.68	42,145
10. Orissa	46,466	562	1.21	834
11. Punjab (including Hariyana)	21,269	5,306	24.95	41,085
12. Rajasthan	32,241	1,179	3.66	6,962
13. U. P.	112,624	9,773	8.68	17,591
14. West Bengal	38,465	1,209	3.12	431
15. Nagaland	814	8	1.00	—
India (excluding Kerala)	5,44,239	49,629	9.12	4,99,989

Table 6

*Share of Irrigation and Industry in the
Total Consumption (Including net import)
of Power in West Bengal,
1959-60 to 1967-68*

Year	Total consumption within the State	Consumption by Industry	Consumption by Irrigation	%share claimed by Industry	%share claimed by Irrigation
1959-60	2,320.1	1676.0	3.3	72.2	0.14
1960-61	2,678.5	1989.1	2.6	74.3	0.10
1961-62	2,723.5	1966.2	2.1	72.2	0.08
1962-63	3,203.0	2375.1	2.7	74.2	0.08
1963-64	3,493.2	2629.2	2.5	75.3	0.07
1964-65	3,729.8	2979.8	2.6	75.0	0.07
1965-66	4,010.8	2975.5	4.2	74.2	0.10
1966-67	4,243.7	3047.2	7.7	71.8	0.18
1967-68	4,121.0	3024.2	20.1	73.4	0.49

Source : Economic Review, Government of
West Bengal

Table 7

*Generating Capacity required for Supplying
24,000 million kwh at Different Levels of
Load Factor and Diversity Factor**

Generating capacity required in MW at the		
Load Factor	D. F. of 1.15	D. F. of 1.10
90%	2,500	3,120
85%	3,705	3,304
80%	3,937	3,510
70%	4,500	4,011
60%	5,250	4,680
50%	6,300	5,616
40%	7,875	7,020
30%	10,500	9,300
20%	15,750	14,040
10%	31,500	28,080
5%	63,000	56,160

* Diversity Factor (*not equal to*) $\frac{\text{Installed capacity}}{\text{peak load}}$

Table 8

*West Bengal State Income from (i) Agriculture and
(ii) Industry (including small units) at the 1951-52
Price and at Current Price*

(in Rs. million)

Year	Income at 1951-52 constant price		Income at current price	
	Agriculture	Industry	Agriculture	Industry
1960-61	3,863.7	2604.8	3820.9	2213.0
1961-62	3,741.0	2577.0	4163.2	2375.5
1962-63	3,407.3	2762.1	4042.2	2704.3
1963-64	3,867.9	3445.7	4713.3	3199.1
1964-65	4,282.4	3544.6	5424.2	3571.9
1965-66	3,519.0	3719.2	5359.9	4628.8
1966-67	3,511.1	3573.6	7015.7	4755.3
1967-68	3,800.9	3722.3	9452.5	4781.1
Average per year	3,749.2	3268.7	5499.0	3528.6
Average production as % of 1960-61 production	97.0%	125.5%	143.9%	159.4%
Ratio between average income at current price and that at constant price			1.467	1.080

Source : Economic Review 1968-69, Govt. of West Bengal

Table 9

Index No. of Whole Sale Prices, India

Year	1952-53	1960-61	1962-63	1964-65	1966-67	1968-69
1. Agricultural Commodities	100.0	123.8	123.3	155.8	199.0	216.7
2. Manufacture	100.0	123.9	128.8	137.3	163.0	168.6
3. All Commodities	100.0	124.9	127.9	152.7	191.3	210.2

Source : Reserve Bank of India Bulletin, May 1969

POWER POTENTIAL OF INDIA

Dr. Manoranjan Chaudhuri

Abstract

The amount of power consumed in a country is a *sine qua non* of its industrial progress and standard of living. The per capita consumption of energy in India in terms of coal equivalent is only 172 Kg. as against 9,201 Kg. in the U.S.A., 7653 Kg. in Canada, 3,611 Kg. in the U.S.S.R., 5,151 Kg. in the U.K. and 1,783 Kg. in Japan.

The primary sources available for generation of electricity in India are coal, lignite, water resources, oil, natural and refinery gases and nuclear fuels. Poor quality coals with high ash content and middling from coal washeries that cannot be transported economically over long distances are burnt in boilers for generation of energy. The thermal power stations operating in different parts of the country, meet the energy requirements of large number of industrial plants. Hydro-electric generation provides a cheap source of power. India is a land of rivers. The total hydro-power potential of India's rivers has been estimated at 41 million KW at 60 per cent load factor. The installed generating capacity of hydro-electric power stations in India was 1.85 million KW in 1960-61 and 4.14 million KW in 1965-66. Oil also gradually becoming an important source of

power in India with increasing exploitation of oil resources and the setting up of a number of oil refineries in various parts of the country. As a result of exploration work during the past few years oil has been struck at Moran, Hugrijan and Nahorkatiya in Assam and Ankleshwar in Gujarat. Oil reserves at these places have been estimated at 100 million tonnes. The thermal generating capacity including oil plants at the end of 1960-61 was 3.73 million KW which rose to 6.03 million KW at the end of 1965-66.

The first atomic power station of India at Tarapur in Maharashtra taken up towards the end of the Second Plan with a capacity of 380 MW is expected to generate electricity in no time. The second atomic power station at Rana Pratap Sagar with a capacity of 200 MW is expected to come into operation in the early part of the Fifth Plan period. The third atomic power station with an installed capacity of 400 MW at Kalpakkam in Madras is expected to be completed in the Fifth Plan period. A comparative study of investment per Kilowatt and the cost of generation per Kilowatt hour in typical hydro-thermal and nuclear stations in the country shows that the cost per Kilowatt hour is 2.9 paise for hydro, 4.6 paise for coal-based thermal and 5.8 paise for nuclear stations.

According to the assessment of the Energy Survey Committee the requirements of installed capacity consistent with 6 per cent and 7 per cent growth in national income would be 19.2 and 21.41 million KW in 1971, 28.7 and 33.90 million KW in 1976, 46.2 and 55.70 KW in

1981 as against 5.6 million KW for both the growth rates in 1961.

A proper time phasing for new projects is necessary so that large surpluses or shortfalls in any year may be avoided:

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Introduction

The amount of power consumed in a country is a *sine qua non* of its industrial progress and standard of living. The per capita consumption of energy in India in terms of coal equivalent is only 172 Kilogrammes as against 9201 Kg. in the U.S.A., 7653 Kg. in Canada, 3611 Kg. in the U.S.S.R., 5151 Kg. in the U.K. and 1783 Kg. in Japan.

Sources of Power in India

The primary sources available for generation of electricity in India are coal, lignite, water resources, oil, natural and refinery gases and nuclear fuels. Wind power, solar, geothermal and tidal energy might constitute future sources subject to appropriate technological developments.

At present more than 60 per cent of the energy consumed in the country comes from non-commercial sources like cattle dung, wood, charcoal and farm waste. According to an estimate the amount of cattle dung annually available in India is 1200 million tonnes (net weight) of which 400 million tonnes, are used as fuel and 215 million tonnes as manure, the balance being wasted. On the basis of energy content 400 million tonnes of cowdung is equivalent to 46 million tonnes of coal. Fuel wood consumption in the country has been estimated at

60 million tonnes which in terms of coal equivalent equal roughly to 35 million tonnes of coal¹.

The commercial sources of energy include coal, oil, water and nuclear fuels.

Coal

Poor quality coals with high ash content and middlings from coal washeries that cannot be transported economically over long distances are burnt in boilers for generation of electrical energy. The thermal power stations operating in different parts of the country meet the energy requirements of large number of industrial plants.

The Committee on the Conservation of Metallurgical Coal (1949) estimated the reserves of coking coal at about 2000 million tonnes. The Committee observed: "This figure, however, may well be halved unless precautions (notably compulsory stowing) are taken in mining and unless steps are taken to use blends containing weakly coking coals and to wash the inferior grade of coking coal."

The Geological Survey of India estimated the reserves of both Gondwana and Tertiary coals at 42,649 million tonnes lying within a depth of 2000 feet. These reserves have been divided broadly into two categories :

Category A includes low volatile coals with less than 15 per cent ash and high volatile coals with less than 13 per cent ash. Category B includes coals inferior to the above. The coal reserves under both these categories are shown in the following table.²

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1. M. R. Chaudhuri, *Indian Industries—Development and Location*, Calcutta 1966, p. 174.
 2. *Ibid.*, p. 175

Table 1

Coal Reserves in Category A
(Figures in million tonnes)

	<i>Upto 1000 ft. depth</i>		<i>From 1000 to 2000 ft. depth</i>		Total
	Coking / Non-coking		Coking / Non-coking		
Gondwana					
Coal	2,294	3,446	935	2,079	
Tertiary					
Coals	—	1,250	—	800	
	2,294	4,696	935	2,879	10,804

Table 2

Coal Reserves in Category B
(Figures in million tonnes)

	<i>Upto 1000 ft. depth</i>		<i>From 1000 to 2000 ft. depth</i>		Total
	Coking / Non-coking		Coking / Non-coking		
Gondwana					
Coal	7,932	13,970	3,985	3,475	
Tertiary					
Coals	—	2,483	—	—	
	7,932	16,453	3,985	3,475	31,845
Grand total (of Categories A and B together)					42,649*

* Besides inferred reserves lying within a depth of 3000 to 4000 feet have been estimated at 79,392 million tonnes.

According to these estimates the known reserves of coking coals in Category A are 3259 million tonnes and of non-coking coals 7,575 million tonnes. The non-coking coals can be profitably utilised for generation of thermal energy.

The main coal producing areas in India includes Raniganj, Jharia, Giridih, Bokaro and Karanpura in the Damodar Valley in Bihar and West Bengal, Chanda in Maharashtra, Singareni in Andhra Pradesh, Talcher in Orissa, Khasi, Jaintia and Garo Hills in Assam. In addition lignite (brown coal of low calorific value and usually very high moisture) occurs in the South Arcot District of Madras State and in small quantities in Bikaner. The coals of West Bengal and Bihar and of the outlying fields are of bituminous variety and may be broadly classified under the following two types :

(i) Coking coals—low medium volatile (20 per cent to 33 per cent with low moisture from 1 per cent to 3 per cent). These coals have strong coking properties and are generally suitable for manufacture of metallurgical coke.

(ii) Non-coking coals—high in volatile (usually over 33 per cent), moderately high in moisture from 4 per cent to 15 per cent. These coals have weakly coking or non-coking properties and are used for steam generation and other purposes. Certain coals are, however, intermediate in type and lie between (i) and (ii) above. Coals of Jharia, Bokaro and Giridih are of coking type and those of Raniganj and Karanpura are mostly of non-coking type. Small quantities of coking coals are found in the western parts of Raniganj field. Coals in the outlying fields are mostly non-coking.

The lignite coals are of low calorific value but it is often low in ash and can be used in thermal power stations near the mines ; in the manufacture of briquettes (domestic fuel) of gases and liquid fuels, and of chemicals³. In South Arcot district, the Government of India have undertaken to utilise the same.

3. *Ibid.* p. 178.

Petroleum

Oil is also becoming an important source of power in India with increasing exploitation of oil resources and the setting up of a number of oil refineries in various parts of the country. India produces about 400,000 tonnes of petroleum annually from the Digboi field in Assam. As a result of exploration during the past few years, oil has been struck at Moran, Hugrijan and Nahorkatiya in Assam and Ankleshwar in Gujrat. Oil resources at these places have been estimated at 100 million tonnes. The thermal generating capacity including oil plants in India at the end of 1960-61 was 3.73 million Kw. which rose to 6.03 million Kw. at the end of 1965-66.

According to a tentative estimate the potential oil bearing areas in India cover 1,036,000 sq. kilometres comprising Assam including Tripura and Manipur, West Bengal, Punjab including Himachal Pradesh, Jammu and Kashmir, Rajasthan, Cambay-Cutch, Ganga Valley, Madras coast, Andhra coast, Kerala coast and the Andaman and Nicobar Islands. According to geologists, the peninsular parts of India consisting of pre-Cambrian rocks has remained a stable block, through vast periods of geological history and thick marine sediments are totally absent from the area. In the extra peninsular parts of India, thick marine sediments exist in many regions. Considering the fact that much of the extra peninsular area has been subjected to intense disturbance, petroleum in quantity will be limited only to a few areas where the geological structure is favourable (namely where the sediments are generally arched forming anticlines).

The work of oil exploration at present is conducted by four concerns in India. The Assam Oil Company and the Oil India Limited operate in Assam, the Stanvac project operates in West Bengal and the Oil and Natural Gas Commission in the Punjab, Himachal Pradesh, Jammu, U. P., Rajasthan, Bombay and Kutch. Under the auspices of the Oil and Natural Gas Commission, drilling operations are in progress in Cambay,

Ankleshwar, Sibsagar, Jawalamukhi and Hoshiarpur. With increasing exploitation of oil resources of the country and the setting up of a number of oil refineries, the use of the furnace oil, refinery wastes and natural gas for power generation has been found economical near the oil fields and refineries. The cost of generation of power in diesel power station is high and this type of generation has been found economical near fields and refineries.

Water Power

Hydroelectric generation provides a cheap source of power, since unlike other modes of generation, no fuel is consumed and the flowing water provides an inexhaustible source of energy.

The installed generating capacity of hydro-electric power stations at the end of 1960-61 was 1.85 million Kw. and it rose to 4.14 million Kw. in 1965-66. The first water power station in India was established at Sivasamudram on the Cauvery river in 1902 in order to meet the needs of the Kolar Gold Mine as well as the municipal needs of the State. Subsequently a number of other power stations were built in other parts of the country,

The industrial centres in South India depend largely on water power because of the paucity of coal there on the one hand and facilities for generation of water power on the other.

The hydro-electric power resources of India are vast but these resources have not been surveyed completely. A Committee appointed to survey the water power resources submitted its preliminary report in 1919 and a final report in 1921 and indicated a minimum continuous water power potential in India of 3.5 million Kw. The estimate, however, is still incomplete. According to the Planning Commission

the total hydro-electric power potential of India is about 41 million Kw. distributed as follows :

Table 3

Water power potential of India

	Million Kw
West flowing South Indian rivers	4.35
East flowing South Indian rivers	8.63
Central Indian rivers	4.29
Rivers of Ganga Basin	4.83
Rivers of Indus Basin	6.58
Brahmaputra and others	12.49
Total	41.17

The rivers of India fall under three groups : (1) the snow-fed rivers of northern India, (2) the rain-fed rivers of central, southern and eastern India, and (3) the tidal rivers. Three important river systems, viz., the Indus, the Ganga and the Brahmaputra owe their origin to the Himalayas. The rivers of northern India are snow-fed and flow all the year round. The supplies of water in these rivers in winter, however, is low. During the spring, the rivers rise with the melting of the snow. With the break of the monsoon these rivers swell further and create flood during the rainy season. During the dry season from October to March, supplies in these rivers fall considerably.

The rivers of central, southern and eastern India are torrential in character inasmuch as they have no snow fields at their heads and their supplies depend entirely on rainfall. The rivers carry large supplies of water during the monsoon

period. During the dry period from October to June the flow in the rivers decreases considerably and they are reduced into mere trickles.

Among the tidal rivers, which receive plentiful supply of water during the high tide, those of the deltaic tracts of West Bengal deserve mention. The sea is their main source of supply and their navigability and utilisation for the other purposes depend wholly on the supply of tidal water.

From some of the major rivers detailed gauge and discharge observations are available. These observations are mainly in connection with the existing or projected irrigation works. A complete hydrographic survey of the country has yet to be made. According to the estimates made by the Irrigation Commission in 1901-1903, the total annual surface flow in the Indian rivers (as it was then but excluding Burma, Assam and East Bengal), was 1.4441 billion cubic metres (1170 million acre feet) of water. A recent estimate of the water resources of the country based on an empirical formula correlating the river flow in each basin with its rainfall and temperature gives the total annual flow as equivalent to 1.6 911 billion cubic metres for the Indian Union. Of this hardly 10 per cent is now used for purposes of irrigation—the rest of the flow goes waste to the sea.

Though hydro-generation is cheap it takes a long time to set a hydel station and comparatively a large outlay is necessary. The specific method of power generation suited to an area therefore has to be taken into consideration. The key factors that are to be of installed capacity, the foreign exchange component, the cost per kilowatt hour generated, the duration of project construction, its impact on other allied activities, such as coal mining, washeries, irrigation, exploitation of natural gas, stimulus to the development of new technology among other factors.

A regional grid is going to be developed in the south. Three 220 KV lines for inter-state transfer of power likely to be developed to link the Madras, Andhra, Mysore and Kerala

systems. In northern India as well the different hydel and thermal plants are being gradually linked for effecting economy in utilisation.

Nuclear Energy

Considerable opportunities exist for the generation of atomic energy in India. The monazite sands found on the beaches of Kerala and Madras coasts contain one of the largest deposits of thorium in the world containing no less than 200,000 tonnes of thorium in a concentration of over 9 per cent. A more extensive monazite deposit has been discovered in the State of Bihar as a result of the work of the Atomic Minerals Division. This deposit contains no less than 3 million tonnes of thorium in a concentration of over 10 per cent. India has the largest deposit of thorium in the world.⁴

Work on the establishment of the first atomic power station at Tarapur in Maharashtra with a power capacity of 380 megawatt was taken up towards the end of the Second Plan. Power supply from this station is expected to commence within the current year. Work on the second atomic power station at Rana Pratapsagar in Rajasthan with a capacity of 200 megawatt, started in 1965-66. This power plant is expected to be commissioned in 1970-71. Another unit of 200 megawatt has been sanctioned for this station and is expected to come into operation in the early part of the Fifth Plan period. Proposal to build a third atomic power station with an installed capacity of 400 megawatt at Kalpakkam in Madras has been accepted by the Government. This project is expected to be completed in the Fifth Plan period. By 1970-71 about 580 MW of generating capacity is expected to be available from

4. *Ibid.*, p. 191.

the atomic power stations. Another 600 MW is expected to be generated by atomic power stations in India in the Fifth Plan period.

Other Sources

With the advancement of science and technology it would be possible to utilise solar radiation, wind motion, tidal energy, heat of the earth etc. for power generation in future.

Capacity and Production

During the three Five Year Plans (1st Plan : 1951-56 ; 2nd Plan : 1956-61 ; 3rd Plan : 1961-66) there has been a rapid growth in electric power supply industry. The installed generating capacity which was 2.3 million Kw. in 1950 rose to 3.42 million Kw. in 1955, 5.58 million Kw. in 1960-61 and 10.17 million Kw. at the end of the third plan (1965-66). The target set for the Third Plan was 12.69 million Kw., an increase of 7.1 million Kw. in a five year period. However, the target could not be fully achieved due to difficulties of foreign exchange and delays in completion of some projects. About 2 million Kw. capacity was realised in 1966-67 from the spillover projects of the Third Plan.

Table 4

Growth of Installed capacity
(The growth of installed capacity by
type of plant is set out below)

	(Million Kw) Estimated				
	1950	1956	1960-61	1965-66	1970-71
Hydro Plant	0.56	0.94	1.85	4.14	7.6
Steam Plant	1.59	2.27	3.40	5.61	11.47
Oil Plant	0.15	0.21	0.33	0.42	0.27
Atomic Plant	—	—	—	—	0.58
Total	2.30	3.42	5.58	10.17	20.00

At the close of the Third Five Year Plan in 1965-66, the generating capacity was 8.9 million Kw. out of which 54 per cent was thermal power and nearly 46 per cent was hydro power.

Generating Costs

A comparative study of the investment per kilowatt and the cost of generation per kilowatt in typical hydro, thermal and nuclear stations in the country shows that the cost per kilowatt hours, viz., 2.9 paise for hydro, 4.6 paise for coal based thermal and 5.8 paise for nuclear stations. The nuclear stations operate at a higher plant factor and for a factor of 75 per cent, the cost gets reduced to 4.7 paise. This is cheaper than thermal power produced at coal based stations located far away from the collieries.

Perspective of Power Development

The table below gives the Energy Survey Committee's assessment of the requirements of installed capacity consistent with 6 per cent and 7 per cent growth in national income :

Table 5

Requirements of Installed capacity

Period ending March	(Million Kw)	
	For growth of national income 6 per cent	7 per cent
1961	5.6	5.6
1971	19.2	21.41
1976	28.7	33.90
1981	46.2	55.70

The actual power target to be set for a Plan has to be worked out by a detailed examination of the load requirements of various categories of demand especially in the industrial sector. From various considerations a target of 20·0 million Kw. of installed capacity was set for the Fourth Plan. The figure may be revised because of various difficulties in the implementation of the projects.

The power plan in the coming years is based on the integrated operation of power systems of the neighbouring States and establishment of regional grids. A few centralised load despatch stations and inter-connecting extra high voltage transmission lines will be set up for integrated operation of these power systems.

The five Regional Electricity Boards already set up in the country consisting of representatives of State Electricity Boards and the Central Electricity Authority, will advise on planning of power system in the various regions and their integrated operation and prepare a coordinated programme of overhaul and maintenance of generating plants.

Remarks

The demand of power in India is gradually on the increase consequent upon increasing industrialisation and urbanisation. Difficulties are also experienced in implementing power projects because of inadequate technological advancements. A proper time phasing of new projects is necessary so that large surpluses or shortfalls in any year may be avoided and power production may be conducive to the economic prosperity of the country.

POWER ECONOMICS AND PLANNING IN INDIA

Dr. S. B. Chatterjee

Abstract

There is an alarming prospect of a power famine in our country in near future according to the latest indications from the Government Statistics regarding the installed capacity, firm capacity and peak load figures from 1964 onwards which only reveals the dismal power position of India during the successive Five Year Plan periods. There were various handicaps which prevented the Third Plan to reach its target of 12.69 million KW. The ambitious draft Plan also gives a picture of power generation potential of 80,000 million Kilowatt hours per annum. The impending power shortage is simply due to the failures to achieve the target envisaged under the Third Plan. The pattern of utilization of electrical energy is widespread and electricity from a hydel plant can be used for all types of power purposes in industry, locomotion etc. But nearly 90% of our potential hydel power is still running down to waste. The generation of power in the advanced countries of the world is need-based with sound economic and well-organised system for distribution and utilization to the fullest extent conceivable, but in India this picture is far from satisfactory. The pattern of utilization of electrical energy in this country indicates that most energy is consumed by industry and domestic utilization is at its low level.

Increased urbanization and industrial development, electrification of rural areas, agricultural development, growth in transport etc. demand more and more electrical energy for useful utilization. It is therefore absolutely necessary to give highest priority to the planning of a programme of expansion of electricity generation and its distribution during next few years. It should be the imperative duty of any Government to concentrate on useful electrical projects like hydel and thermal power generation rather than uneconomic and unplanned industrial ventures in the public sector.

The cost of power supply constitutes the most significant factor of the total production cost in several industries in both the public and private sectors. In case of West Bengal the cost of electric generation is much higher despite the proximity of coal deposits and available water bodies. Increase in the price of electricity raises the cost of industrial production and consequently the prices of finished goods all aggravate the inflationary pressures in industrial economy. It is in the interest of such States with large industrial potential to ensure that the cost of electrical generation is maintained at a reasonable and comparative level to attract more new industries for their development with profit and also to check the flight of industrial capital from the backward to advanced states. It is therefore wrong economics for State Governments to enhance the rates for the supply of power frequently in the interest of the income of the exchequer. There is considerable scope for effecting economies by improving the efficiency of generating units, be it hydel

or thermal, in transmission and in administering the Boards. In many cases the differences between the cost of power generation by the State Electricity Board and private undertakings are staggering. There is also no justification to subsidise the cost of rural electrifications by burdening the industrial consumers. Such a wrong policy is detrimental to the development of industries which should have greater priority. A better rate of return may be earned by the Board through reduced costs rather than higher tariffs. This will give a great fillip to rapid industrialization and the State Governments should provide sufficient incentives to industries for this purpose, particularly in case of power intensive industries.

The cost of energy being an important element in the total cost of production of the final product, there is need for long term planning to design the pattern of power supply and to make the best use of available resources with the object of keeping the cost of energy as low as possible. It is therefore necessary to draw up a long term plan with a perspective of say, 30 years with the explicit object of supplying power at the lowest possible cost. Further efforts should be made to obtain maximum benefit from energy produced by keeping a rigid check on the production, transportation and transmission costs of energy.

To achieve the aforesaid objects late Mr. Andrew M. Komora being invited came to India with his vast engineering experience and joined on December 1, 1959 as the Chief Engineer of the DVC. He had experience of

the Tennessee Valley and similar river valley schemes in South America and he helped completion of the first phase of the Damodar Valley Project. He was the Project Manager of TVA in the USA. From his experience he said "The difficulties of the DVC are infinitely greater than were those of TVA, practically all the machinery both construction and permanent equipment must be purchased from abroad...and no experienced construction engineers are available in India". Despite difficulties and complicating factors, the construction of four dams—Tilaiya, Konar, Maithon and Panchet plus the Bokaro Thermal Power Station and the Durgapur Barrage with a net work of canals commanding nearly a million acres had been completed in a decade. According to Harvey Slocum, the famed dam expert and former Director of Construction—Bhakra-Nangal Project—"the overall progress, taking all factors into consideration was good and that the quality of the work was above average..." It will be necessary to complete the balance of the DVC programme by constructing additional Dams for the control of flood and other industrial facilities and this being done, it will remain a source of inspiration for generations to come.

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Introduction

There is an alarming prospect of a power famine in our country and according to the latest indications power shortage will start developing right from the current year of 1968 and onwards.

According to the Fourth Annual Electric Power Survey published by the Central Electricity Authority, though there will be a surplus of 124 MW in the firm capacity over the estimated peak loads during 1967-68, there will be deficits of 211 MW in 1968-69, 684 MW in 1969-70 and 245 MW in 1970-71. The following official statistics regarding the installed capacity, firm capacity and peak load will reveal the present all-India power position.

	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
1. Installed capacity	7321	8918	10321	12885	14556	16180	19422
2. Firm capacity	5012	6121	7235	8921	10235	11316	14420
3. Peak Load	5193	5605	7325	8797	10446	11964	14665
Surplus +	-181	+516	-90	+124	-211	-648	-245
Deficit -							

Though the successive Five-Year-Plans gave a fillip to power generation, the Third Plan target of 12.69 million Kw was not achieved due to various handicaps, namely, foreign exchange difficulty, delays in completion of many projects etc. In the Draft Plan, a provisional target of 20 million Kw of installed capacity, a power generation potential of 80,000 million Kw hours per annum was expected to be created.

The impending power shortage is simply due to the failure to achieve the target envisaged under the Third Plan. The industries of all the advanced countries of the world, and for that matter in our country also constitute by far the largest consumers of electricity and this in short is the pattern of

utilization of electrical energy in our country. Electricity from a hydel plant can be used for all types of power purposes in industry, for locomotion by railways or trams or for domestic purposes, lighting, heating, cooking or refrigeration and not a few industries are entirely dependent on electric power and so they are associated with hydel plants. Our coal and oil resources are limited and are being quickly exhausted. Nearly 90 per cent of our potential hydel power is still running down to waste. Hydro-electric power development is highest in Western Europe, being followed by Japan, USA, Canada etc. The author had the opportunity of visiting recently some of the power stations in Western Europe and USA. Most of these power stations can be taken to be of similar patterns for development and utilization. The Merseyside Power Station can be cited as an example in point with its vast establishments, commissioned in December, 1958. Numerous similar power stations function in the Gulf States of USA which have acquired an outstanding industrial and social outlook with their generating plants more complex but modern with inter connecting services. In these advanced countries of the world the generation of power is need-based with sound economy and well organized system for distribution and utilization to the fullest extent conceivable.

In India the failure to achieve the power target under the Third Plan is to a great extent responsible for the ensuing power shortage. The pattern of utilization of electrical energy in this country indicates that most energy is consumed by industry and domestic utilization is at its low level. The statistics of the total energy generated by all the public utility undertakings in the country reveal that the industry consumed 70.2 per cent in 1962-63, 72.7 per cent in 1963-64 and 71.7 per cent in 1964-65. It is therefore meet and proper to have a need-based planning to cope with the threatened power shortage because if the power shortage materializes, the impact on the development of industry and particularly on power-intensive industries either in the public or in the private sector will be anybody's guess.

Development

Increased urbanization and industrial development, electrification of rural areas, agricultural development, growth in transport and communication all demand more and more electrical energy for useful utilization. The supply of electrical energy must therefore grow ahead of the rising demand if any possible set-back in industrial development is to be averted. It is therefore absolutely necessary to give highest priority to the planning of a programme of expansion of electricity generation and its distribution during the next few years. It should be the imperative duty of the Government to concentrate on useful electrical projects like Hydel and Thermal Power generation rather than uneconomic and unplanned industrial ventures in the public sector.

The public and private sector undertakings should both concentrate on useful utilization of national resources and should avoid all uneconomic wastage of any material whatsoever. The unplanned and uneconomic industrial ventures in any form are liable to give a fillip to consequent industrial inflation and ancillary recessions etc. Sound economic planning with steady investment of capital are the *sine-qua-non* for success of the industrial life of a nation and India is not an exception. Foreign capital or labour are sometimes unavoidable but in the ultimate picture of an industrial life national resources, labour and national planning play the most vital part to raise the nation to industrial maturity as in case of the most advanced countries of the world like USA, USSR, UK etc. not excepting even the comparatively smaller territories of Central Europe, South-East Asia including Japan. In each and every case foreign capital and labour were reduced to the minimum even at the time of their initial growth not to speak of their later developments. When the know-how is broken through nothing can stand in the way of any industrial development, whether commonplace or technical. The last word in the industrial development is power,—physical, economic and social, which together, like the physical

independence of forces, manufacture the proper industrial environment for physical forces to act favourably in time with the national life.

None can say what will be the rate of industrial growth in a particular environment, one may at best surmise or calculate the results on the basis of the existing parameters. But the rate of growth would inevitably depend on a set of complex factors which are themselves variable, depending on time and environment including political influences which are beyond the estimation of most people. If any industrial growth is to occur it must occur in spite of the handicaps through the constant endeavour and co-operation of the people, without which no improvement and development can be expected worth the name.

The cost of power supply constitutes the most significant factor of the total production cost in several industries in both the public and private sectors. In case of power intensive industries, this factor becomes more powerful. Recently the cost of power supply to industries per unit has been progressively rising with the frequent increases in rates by State Electricity Boards and electric power supply organisations all over the country. Moreover, State Electricity Boards are attempting to subsidise rural electrification by raising the cost of electric power supplied to industry. Such an increase in the price of electricity raises in its turn the cost of industrial production and consequently the prices of finished goods, all aggravate the inflationary pressures in industrial economy. This also has an adverse effect on our exports in a country which is already handicapped with a high cost economy and therefore a further increase in the cost of production becomes a matter of serious concern.

In some States, industries appear to enjoy less advantages as compared to industries in other States. The rates charged by Electricity Board in some States are definitely higher than those charged by Boards in some other States. In case of West Bengal the cost of electric generation is much higher

despite the proximity of coal deposits and available water bodies. If the rates of power supply in any State are higher, industrial development is put to disadvantage and power intensive industries in that State would naturally try to move to other States where power is cheaper and there will be flight of capital investment from an unsuitable to a more suitable State thus affecting State economy. It is in the interest of such States with large industrial potential to ensure that the cost of generation of electricity is maintained at a reasonable and comparative level to attract new industries for their development with profit and also to check the flight of industrial capital from backward to more advanced States. The cost of industrial production coupled with some other complex factors like transport, market etc. plays in most part, the dominant role in the success of the industry of a nation and taking into consideration all the above facts, India, and for that matter West Bengal, is far behind the advanced countries of the west. For obvious reasons the industrial growth became stagnant during the foreign regime and after Independence a limited number of projects were undertaken by the Government as an initial step which, during successive Five Year Plan periods, got nourishment, though not adequate, to reach their present stature.

The sites selected for hydel and thermal power generation are not a whit less important in the life of an industrial nation. The national resources should be utilized for the sake of the nation itself which in its turn calls for industrial planning with a view to cope with the increasing unemployment, want of accommodation, increase in the cost of living, particularly in urban areas. Japan's phenomenal development during the last 70 years shows that industrial development is possible even without national resources and raw materials and with their existing hydel and thermal power and with the imported industrial raw materials they have been able to build an edifice of import and export concern on the highest international level, both unique and astounding. Power has been harnessed in Japan in an ideal way and

wastage has been reduced to the minimum with the consequent increase in the industrial potential through sound economic planning.

It is wrong economics for the State Governments to raise the rates for the supply of energy; this is more often than not ascribed to the increase in the cost of operation of the State Electricity Boards and also to ensure a reasonable return. Certain items of cost of materials like coal have shown an upward trend of price in recent years over which the Boards have little direct control. But to counteract this, the Boards have so far shown little concern to maintain their operational costs at a reasonably low level by attempting economics and improving their efficiency. The difference in the cost of power generation by the State Electricity Boards and by the private undertakings is considerable. But there is no justification in subsidising the cost of rural electrification by burdening the industrial and domestic consumers. Such a policy is harmful to the growth of industries. It would be more appropriate if the Boards try to rationalise their cost structure before increasing their charges to bring higher returns. The Boards may earn a higher rate of return through reduced costs rather than higher tariffs as there is enough scope for effecting economies by increasing the efficiency of generating units, in transmission and in administering the Boards.

The need for efficient operation of the State Electricity Boards has been recognised by *proper authorities* emphasizing that each State Electricity Board shall "always keep the costs of generating, transmitting and distributing electrical energy including overheads as low as possible and shall take necessary and suitable steps to this end by periodical reviews." Such advice cautioned that "care has to be taken to safeguard against the tendency to push up the tariff as also the electricity tax or duty beyond certain levels as it may handicap the overall social and economic development." The competent authorities further stressed that

every Board "should strive to operate at the maximum efficiency and economy." In view of such clear enunciation of the need for operational efficiency it is imperative that the State Electricity Boards should strive their utmost to bring about economies in their operational and other expenditures to improve their efficiency.

Planning

The availability of cheap energy will certainly give a great fillip to rapid industrialisation and so the State Govts. should provide sufficient incentives to industries for their development and expansion in general and to power intensive industries in particular. Of late some State Govts. have already taken recourse to granting concessional rates of duty or exempting power-intensive industries from duty or levy to encourage industrial development. Similar measures should be taken by all the State Govts. and that being done, there will be rapid industrialisation in West Bengal which is so necessary for the welfare of the people at the present moment.

The cost of energy supply being an important basic element in the total cost of production of the final product, there is need for long term planning to design the pattern of power supply so as to make the best use of available resources with the object of keeping the cost of energy supply as low as possible from particular installed plants. It is therefore necessary to draw up a long term plan with a perspective of say, 30 years with the explicit aim of bringing down the cost of power supply at the lowest level possible. With the present day know-how of the generating and transmission equipment and with the required economies associated with the problem of power supply it should be easier to supply energy at relatively cheaper rates which will enable the industrial undertakings to earn a reasonable return on their capital investments and this becomes more encouraging in case of a possibility of foreign exports to suitable world markets not

only to earn foreign exchange but also to improve the national economy in various ways than one.

The investment implication of producing cheaper energy over the next few years should be consistent with the annual rates of increase in industrial production. All this calls for a detailed plan for the supply and utilisation of power during a sufficiently longer period ahead. The foreign exchange requirement per unit of production should be minimised because large investments in power developments would require foreign exchange. Planning is also necessary to obtain maximum benefit from energy produced, and this can be attempted by keeping a constant and rigid check on the production, transportation and transmission costs of energy.

Efficient and adequate power generation is *sine-qua-non* for industrial growth and expansion. Public and private sectors should be given the green signal for starting development projects and no ideology or politics should stand in the way of cheap and abundant supply of electric energy if India's industrialisation is to proceed at the desired level.

It is interesting to study the history of India's industrialisation in the background of India's environment, both past and present. After achieving Independence there were days of industrial stagnation during the initial stages until India came to recognise that her economic salvation rests entirely on rapid industrialisation and thus the seed germinated to produce the desired tree on the desired soil. To effect industrial developments some projects should be started and as such, late Mr. Andrew M. Komora being invited, came to India with his vast engineering experience and noble mission to help India which resulted in his joining on December 1, 1950 as the Chief Engineer of the DVC. He had the experience of the Tennessee Valley of the USA and similar other river valley schemes in South America to help completion of the first phase of the Damodar Valley Project. He was the Project Manager of the TVA in USA. From his experience he said "The difficulties of the DVC are infinitely greater than

were those of TVA. Practically all the machinery—both construction and permanent equipment—must be purchased from abroad, and no experienced construction engineers are available”. Despite these difficulties and other complicating factors, the construction of four Dams—Tilaiya, Konar, Maithon and Panchet along with Bokaro Thermal Power Station and the Durgapur Barrage with a network of canals commanding nearly 405,000 hectares had been completed in a decade. According to Harvey Slocum—the famed dam expert and former Director of Construction, Bhakra-Nangal Project—“the overall progress, taking all factors into consideration was good and that the quality of work was above average...”

So from all these expert views it is evident that the wheel of industry in India began initially to move slowly but gradually gathered momentum for more and more progress. The overall progress may not be phenomenal but it is worth the name and it is possible for India to solve her industrial problems with her present energy, industry and application. But it will also be necessary to complete the balance of the DVC programme by constructing additional few dams not only for the control of devastating floods like the recent ones but also these will offer immense industrial facilities, and this being done in near future, it will remain a source of inspiration for generations to come.

ON THE POSSIBILITIES OF MANUFACTURE OF A USEFUL BUT
LITTLE KNOWN FERTILISER WITH COAL USELESS AS FUEL
AND WITH SECONDARY POWER FROM HYDEL STATION

T. R. De

Abstract

The manufacture of a fertiliser "Nitro-lime" has been advocated in this paper. This fertiliser, though not new, has lost its use in India. In fact as a fertiliser it has been found superior to Ammonium Sulphate. The manufacture has been recommended in this paper by using the friable and normally unusable metamorphosed coal of the Bengal Himalaya where the potentiality of obtaining cheap secondary electric power, which is so important for this industry, from Hydro-electric source is reasonably good.

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Bengal is the poorest of all the states in India. She has the maximum density of population but the fertility of her lands is fast declining with the nett result that Bengal, which was once a surplus area from the point of view of food production, has become a deficit area all round. The position has become extremely alarming and only irrigation is not at all sufficient to meet the situation. The lands need fertilisers very badly. The cultivators still now have practically little knowledge and inclination to improve the condition and the production of their lands with the help of fertilisers. Not to speak of artificial fertiliser—they do not even care to use the little farmyard manure that they have already at their disposal. So they must be trained to the use of fertilisers and if necessary, their hands must be forced for applying fertilisers to their lands. But at the same time it must be remembered that these fertilisers must be sold to them at quite a low price and, if necessary, be subsidised.

Now the question of the kind of fertiliser suitable for the land and its procurement comes in. The compost or the farmyard manure does not come in the purview of this paper, of course. The ingredients that are required most by the soil are nitrogen, phosphate, potash and sometimes lime. The popular fertilisers are ammonium sulphate, ammonium phosphate, super-phosphate, etc., and in Bengal the most popular seems to be ammonium sulphate, mostly due to propaganda perhaps.

But it is necessary to see if ammonium sulphate is quite suitable for the soil of Bengal and if it will be proper to consume an imported material like sulphur for its manufacture and if it will be proper to use gypsum when we have to rail it all the way from the Punjab and Rajputana and if such a good quality coal like the Bengal coal which is so badly needed for the industries should be consumed for the purpose, when there are sources of coal which might answer quite well for the manufacture of a fertiliser but is unsuitable for fuel purpose.

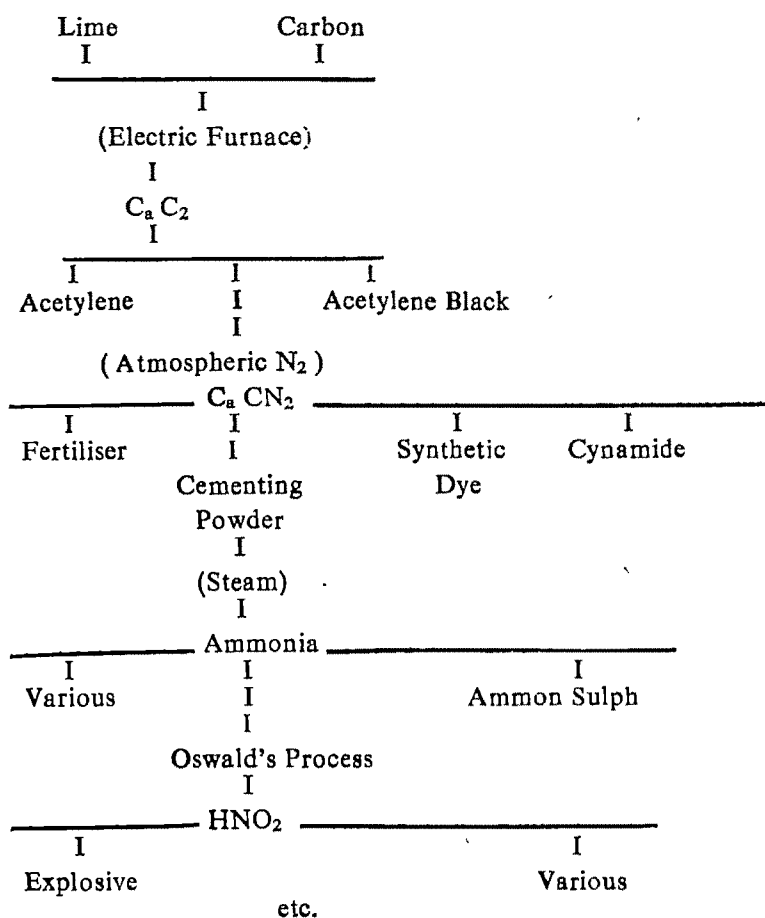
Now let the question of the use of ammonium sulphate be considered. The soil of Bengal, specially the less fertile part of it, is more or less acidic. And it would be more acidic with the use of ammonium sulphate. This is the general sad experience of the cultivators of Bengal who after using this fertiliser for a few terms find the soil gradually dying in respect of crop-producing capacity. And to cope with it an extra heavy dose of lime is automatically needed, thus increasing the cost of production of crops.

Last but not the least of all is that the otherwise precious part of the fertiliser, the sulphur portion of it, is lost and lost for nothing. So we must look for some other fertiliser which will in no case be detrimental to the soil and preferably be not wasteful as well (unlike ammonium sulphate which wastes the sulphur component of it for nothing) and must be cheap and whose raw materials would be easily available.

With the above points in view calcium cyanamide (CaCN_2) deserves attention. This is a fertiliser the raw

materials for the manufacture of which seem to be available in plenty in Bengal and round about. It needs no drawing of the precious fuel-coal of Raneeganj and Barakar fields. The installation of plants for the manufacture of calcium cyanamide or nitrolime will also work as a starting point of a group of industries like the manufacture of nitric acid and explosives, which are all so very important for independent India.

The following is the group that is commanded by lime-carbon industry (Pring) :



Now, at present let us deal only with CaCN_2 . Both the components in CaCN_2 —the calcium and the nitrogen—are useful for soil.

At Richhai (C.P.) experiments conducted for five years (1930-35) to compare ammonium sulphate and calcium cyanamide as fertilisers for paddy applied at the rate of 100 lbs. per acre on light sandy loam indicated that calcium cyanamide was better than ammonium sulphate, irrespective of time of application. So definitely the manufacture of nitrolime deserves attention all the more.

The manufacture of nitrolime starts from the manufacture of calcium carbide (CaC_2), a thing which is not sufficiently manufactured in India at present and which in itself is a very important item for industrial India, as the source of acetylene gas.

Manufacture of (CaC_2) starts from coal (carbon) and lime (calcium). These two are fused in electric furnace giving calcium carbide popularly known as carbide only. According to some authority coal should be of anthracite variety with the maximum of fixed carbon (in the region of 90 per cent) and minimum of ash (max. 5%) and lime stone should also be of the purest variety containing nearly 97 per cent of CaCO_3 .

Unfortunately anthracite is not available in India though the purest variety of lime stone is more or less available.

But it has been found that coal with a fixed carbon content of about 57 per cent and lime stone containing about 96 per cent CaCO_3 can give CaC_2 of 83 per cent purity and the market standard of CaC_2 is only 80 per cent pure.

We have in the Himalayas (Bengal) coal with about 60 per cent fixed carbon and lime stone of the purest variety (95%). Even if the existence of such a pure quality lime stone is not found to be in plenty, the less pure variety can be depended upon, as it is mainly calcium cyanamide we are after, and not calcium carbide. The purest variety of lime can be

consumed only for the manufacture of calcium carbide to be used as calcium carbide.

The coal stock of Himalayas deserves special attention because though it is from the point of view of fixed carbon contents, comparable with the best coal from Raneeaganj or Jharia, a good portion of it is very difficult to transport and use as fuel except in the patent form as it has in many places become friable on account of metamorphosis. So the best way of utilising this stock is to use it as raw material in chemical manufactures, thus utilising the carbon content. This will also relieve the coal fields of Raneeaganj and Jharia from being drawn for purposes other than fuel and metallurgical. The Himalayan coal is also low in phosphorus content which is important in the manufacture of $C_a C_2$.

Next comes nitrogen. Calcium carbide after being produced in the electric furnace is to be heated in an atmosphere of nitrogen at about 1100 deg. to produce $C_a CN_2$.

This nitrogen can, as it seems, be had most cheaply by way of producer gas. The plant should not be very costly and the raw materials are available in plenty in the hills of the Himalayas.

The production of electric power is one of the most important items in the scheme. Whether hydro-electric power or thermal power is to be used will depend on the cost of production from each source.

This power question is a matter of thorough investigation, as hydro-electric power, popularly thought as cheap power, cannot usually compete with thermal power if the power station for the latter is situated on coal-bed and if hydro-electric is installed for this industry alone. But if some of the big rivers of Himalayas are harnessed by the Government for power for industries in general and if on account of very high load factor and the ability for utilisation of seasonal or secondary power the cyanamide industry is given a special concession rate, hydro-electricity may be used with profit.

It should be remembered that it is cheap hydro-electric power that has made Norway the pioneer in carbide and cyanamide industries.

The problem of procuring carbon electrodes for the furnace is also an important one. There is another industry—the aluminium industry—which consumes plenty of these electrodes and in collaboration with this industry arrangements may be made to manufacture these electrodes in India instead of their being imported.

It is, I think, worth while taking this matter up for investigation to see if these manufactures would prove to be beneficial for Bengal and for other provinces as well, from the point of view of conserving good coal and manufacturing a good fertiliser at the same time.

HYDRO-ELECTRIC POWER IN THE DEVELOPING COUNTRIES OF SOUTH EAST ASIA

Arabinda Biswas

Abstract

The countries of South East Asia, namely, Burma, Malayasia, Thailand, Indonesia Indochina, Phillippine and British Borneo deserve special interest regarding their significant share in the world's total potential hydro-electric power. But due to long years of foreign dominance on their economic structures the status of manufacturing in these States is notably low and the primary problem facing any considerable industrial development is power. In the absence of the orthodox sources of power, i.e. coal and oil, the huge potentialities of water-power amounting to some 166,000 million KW are the only noteworthy considerations about these countries' future achievements in industrial fields.

Already, there are signs for a trend of shift from coal and oil to water-power, particularly in Burma, Malaya, Phillippines and Indonesia in order to keep pace with steady rate of urbanisation as well as the change from commodity production to local processing.

Although the progress can never be compared to that in the western nations, some of the projects like the Yanhee (560,000 KW) in Thailand, the Ashaban (1 million KW) in Indonesia deserve mention.

It should be noted that the potential energy from many of the rivers has not been estimated as yet due to a lack of hydrologic survey, and due attention on this matter is of prime importance before the nationalist government.

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The present paper deals with the status of hydro-electric power in the developing countries of South East Asia, namely, Burma, Malayasia, Thailand, Indonesia, Indo-China, Philippines and British Borneo.

A practical difficulty regarding the assessment of the water power resources and their state of development in these countries lies in the fact that adequate up-to-date and reliable data are not available from these lands. The data supplied by the United Nations publications on "Multipurpose River Basin Development" correspond to figures of 1955-1959, and are not wholly comparable since they refer to different years for different countries. The problem of non-availability of data is particularly felt in regard to Indo-China, namely, North and South Vietnam, Cambodia and Laos. Hence these states, although most important from the standpoint of world politics, have been excluded from the major part of the current discussion.

The reason why South-East Asia has been chosen is that these islands and peninsulas form the most important single group of developing countries with close similarities in geographical, historical, political and economic aspects—all struggling in their attempts to come out of the danger of foreign dominance in their economic fields.

The new nationalist governments, however, are facing certain problems towards achieving the desirable economic goals of removing the European plantations, mines and

business concerns. But it appears that so long the economic development depends upon the forms of energy obtained from mineral fuels, South-East Asia has little scope for competing with China or India in respect of trade in manufactured commodities. The very small internal markets stand in the way of any major industrial development. The problem of prime importance is power and the primary duty of the nationalist governments is to solve this problem.

Perhaps it would be convenient for us to have a casual look on the region's potentialities, regarding her power resources. Coal, the most widely used form of energy, is practically negligible both in reserves and in production. The table below shows the production figures :

<i>Countries</i>	<i>Year</i>	<i>Coal Production</i> (tons)
N. Vietnam	1960	2,600,000
Br. Borneo	1960	2,000,000
Indonesia	1960	640,000
Philippines	1960	140,808 (lignite)
Malaya	1959	75,000
Burma	1960	300,000
Thailand	1960	109,358 (lignite)

The above figures present a dismal picture of the coal prospects of S. E. Asia. Most of the coal again is not suitable for coking and metallurgical purposes. Only in British Borneo, the coal is compared to the good quality Australian coal.

The prospects of oil seem some what better. Indonesia and British Borneo have sizeable reserves of petroleum and the productions of these countries in 1959 were respectively 18,218,000 and 5,446,000 tons. The corresponding figure in Burma was 529,000 tons. Whatever may be the real position of these lands regarding the supply of fuel oil it should always be remembered that oil is not suitable for basic heavy industries and the only other condition to be examined is that of

hydro-electricity which so far has been developed only on a minor scale. The potential has been estimated at 166,000,000 Kwh. per annum. The well-distributed high rainfall and the predominance of slopes are assets for water-power development. The bed-rock conditions, except the loose volcanic materials of Java, are not unfavourable. But the enormous water-power resources are mainly located away from the proximity of the centres of greatest concentration of population.

The States of Indonesia, Malaya, Burma, Philippines and British Borneo are all particularly suited for the development of hydro-electric power. Although many of the rivers have not been surveyed at all owing to inaccessibility, the total potential should be enormous. The following table shows the potentialities of some of the countries :

<i>Countries</i>	<i>Potential hydel power</i> (in million kilowatts)
Indonesia	2.86
Philippines	3.50
Burma	3.73

Although manufacturing activities are little developed in the countries of S.E. Asia there are considerable scope for the development of certain mineral-based industries from the reserves of iron, bauxite, tin, tungsten and gold. The basic raw materials like iron and bauxite are however situated without convenient location to the power. There is also a good prospect for agro-based industries like agricultural processing, cotton and jute textiles. Much however, depends on future development of power, chiefly hydro-electric, which seems to be the only possible outlet from the power enigma.

It may be convenient for our purpose to review the conditions of hydro-electric development in different countries of South-East Asia, one by one.

Burma : Burma has the largest potential hydro-electric power in South-East Asia, but until very recently little had been done towards realising the benefits of the huge possibilities. In the pre-war period the total installed capacity was about 17,000 Kw. much of which was destroyed during the war.

In 1952, there were only two hydro-electric plants producing jointly a little less than 1000 Kw at Maymo and Mogok. Most of Burma's power requirements were supplied by the Bengal-Bihar Coal basin in India and by imported and indigenous fuel. Only recently, operation has started on the Kalewa coal deposits utilised for the production of pulverised fuel in Central Burma. But the Burmese foreign trade figures indicate that Burma still has to import a large amount of coal, coke and mineral oil from other countries, while not even 2 percent of her enormous water power resources has been developed. At present the only project of considerable importance is the Balu Chaung Project near Loikaw with a total capacity of 84,000 Kw. The Balu Chaung Project was originally designed to supply power to industries like fertiliser, metal refining, explosive and cottage industries in the vicinity of Nam Pawn.

There are five other future projects under construction and investigation. These are the Mu River Project with a capacity of 50,000 Kw, the Yamethin Project with 40,000 Kw, the Tenasserim Division Project with 150,000 Kw. and the Alam Project in upper Irrawaddy basin with one million Kw. The completion of these projects is still far off, but it is certain that in near future the benefits from these projects will enable the Burmese economy to do away with foreign dependence at least in respect of power. The Pegu project is on way to completion which will supply 15,000 Kw. to the Rangoon-Pegu-Henzada area while Saingdin and Paunglaung Power Projects will add another 58,000 Kw. very soon.

Malaya : There has been no total assessment of the hydel potential of this nation. The largest single installation is the

Perak River Hydro-electric Power Company with a capacity of 27,000 Kw, which is to be trebled very shortly. Other projects are the private installations with the Talam mines, French Tekka mines, Idris mines, Raub gold mines and Rehman mines which together produce some 13,000 Kw. annually. The plants, however, enable the neighbourhood of Kuala Lumpur to be well supplied with electric power, but the rest of the country is left in darkness. In spite of the low status of manufacturing industries in Malaya, the demand for electricity increased by 18.3 per cent in 1957, and it is desirable that the trend of this steady rise in demand should be met with hydel power as far as possible, even if it demands modernisation of the mining methods. Mention must be made of the fact that in 1959 Malaya imported mineral fuels worth M/s 129 million mainly from Hongkong.

With these considerations in retrospect there are two commendable schemes under construction :

a) The Cameron Highland Scheme (Stage I) with four installations each with 25,000 Kw. to generate 286 million Kwh. of hydro-electricity to meet the requirements of the western slopes of the country, and

b) The Robinson Falls Scheme with a capacity of 900 Kw.

There are also several other projects under investigation, the chief among them being the Stage II of the Cameron Highland Scheme expected to produce another 120,000 Kw. in future.

Indonesia : Indonesia is particularly suitable for the development of hydro-electricity chiefly because of its situation in the equatorial region with favourable stream flows and many high-level inland lakes. The estimated potential is 2.86 million Kw. In 1950, the total installed capacity for Indonesia was 190,008 Kw. out of which Java alone produced 184,746 KW.

In Indonesia, unlike other South-East Asiatic countries, hydro-electric power plays a major part in the economy of the country.

<i>Area</i>	<i>No. of plants</i>	<i>Total Capacity</i>
Western Java	8	61,170
Central Java	4	33,130
Eastern Java	5	44,700
Sulawesi	2	10,100
Sumatra	2	2,595

Source : Multipurpose River Basin Development,
United Nations, Flood Control
Series No. 14.

There is a considerable net work of high-tension transmission lines connecting the different hydro-electric, thermal and diesel power stations. In the post-war period certain trends in the Indonesian economic structure have increased the demand for electricity to a great deal. These trends are :

a) The sudden rise in Urban population due to internal migration ; and

b) The gradual shift of the agricultural economy to one of reconstruction and industrial expansion.

Although diesel power plants were rapidly installed, the power from all public sources could meet only 40 per cent of the total demand ; and although Indonesia is the leading country in S.E. Asia in respect of developed hydro-electric power, this shows a pronounced regional imbalance. The large promises offered by Sumatra and other islands have been totally neglected. Even in Java, the Djakarta-Bandung area is precariously placed regarding power supply.

To meet the growing demands of electric power the Government has proposed a power scheme in the Djatiluhur Project with an ultimate capacity of 125,000 Kw. It was expected to come in operation by 1963. The most outstanding among the projected schemes is the Asahan Project in Sumatra expected to produce over a million Kw. of hydro-electricity which will meet the needs of the aluminium, super-phosphate, paper and cement industries of Sumatra. By 1965 Indonesia was expected to produce a total of 202,000 Kw. of hydro-electric power from eleven new plants in Java, Sumatra, Celebes and Borneo.

Philippines : These islands are really very rich in potential hydroelectric resources but still now the share of developed capacity is very low. The first major hydro-electric project—the Caliraya Project—started production in 1941 and was rehabilitated in 1950. By 1955 several major projects were undertaken by the National Power Corporation and these were expected to produce 570,000 Kw. of hydro-electric power by 1959. According to information available, although the completion of these projects were in sight the production was in the vicinity of 250,000 Kw. in 1959.

The dearth of local coal and oil poses a serious obstacle in the way of any large scale industrialisation. Hitherto, the majority of the power was supplied by imported fuel from outside and a little good quality lionite mined at Cebu. So far as the prospect of mineral-based industries are concerned, Philippines have considerable wealth in copper, gold chromite, iron and some other minerals like zinc, lead, silver and mercury ; and regarding the possibility of hydro-electricity it is placed even at a better position than Japan where the stream flows are not available in winters. It is a healthy sign for the Philippine economy that it is planning for further development of hydro-electric projects. Already four major hydro-electric plants have been set up, namely Ambuklao in the Mountain Province, Northern Luzon with a capacity of 75,000 Kw. Caliraya-Lumot in central Luzon with 36,000 Kw.

and the Maria Christina (Stages I and II) with 50,000 Kw. in Mindanao. Other projected plants of considerable importance are the Binga (100,000 Kw), Marikina (180,000 Kw) and the Maria Christina Falls (III, IV and V) (150,000 Kw).

The modern factory industries in the form of agricultural processing date back to 1939, while the consumer goods manufacturing industries have been installed during the Commonwealth regime. The industrial focus is still Manila with its suburbs. There is a new industrial area growing in Cebu with access to local lignite and hydel-power from the Maria Christina Falls. The estimated demand in the Manila-Baguio region for electric power in 1958 was 145,000 Kw. The industries near Cebu which include iron, ammonium sulphate, calcium carbide and cement would also require a large amount of cheap power. Thus markets have already been created in the form of industrial agglomerations and a co-ordinated growth of power and manufacturing is in sight.

Thailand : The absence of coal and oil is even more seriously felt in Thailand. Only since 1955, a small quantity of lignite is mined at Mae Moh near Lamang. The traditional fuel in Thailand is charcoal which is again showing signs of exhaustion. The limited reserves of foreign exchange is mainly spent on import of fuel oils. Since 1953, in a five-year industrial plan, the Bangkok-Thonburi area has attracted various small and medium sized industries thereby setting a considerable demand for cheap power. The National Economic Development Plan of 1961 proposed to raise the industrial income from 10 per cent to 12 per cent of the national income, but industrial improvements will always face the serious power crisis unless and until there is a real progress of hydro-electric development, the potentialities for which in the projects under investigation amount to a little less than a million Kw. None of these projects had been developed prior to 1968 when the Yanhee Project on the Me Ping, some 420 Kilometres north-west of Bangkok, came into operation. This project at

present has total capacity of 140,000 Kw which is to be increased four times by 1974. The need for further development of such projects lies in the fact that Thailand's dependence on foreign sources of fuel is a major handicap against any positive step towards industrialisation.

British Borneo : British Borneo is perhaps better supplied than any other South East Asiatic Country in respect of coal and mineral oil. Reserves were not utilised as the demand for electric power was never felt seriously. Naturally, hydro electric potential remained undeveloped and unassessed except in one river—the Padas in the South-West North-Borneo where investigations were made by the British Aluminium Company. It was found that the potential hydro-electric power of this river could be as high as 352,000 Kw. The proposed dam site is located at Penotal Rock near Tenom.

In conclusion, the observations may be summarised as follows. The colonial regime in South East Asia neglected the various industrial possibilities including agricultural processing and the foremost economic activity was confined to commodity production. During the commonwealth regime there is a gradual shift from commodity production to local processing of agricultural products as well as of the mineral resources. There is a great scope for modernizing the processes of manufacturing and mining and consequent industrial expansion in countries like Malaya, Indonesia, Philippines and Burma. Although the status of manufacturing is still low, markets for power are by no means lacking in or near the urban centres like Kuala Lumpur, Bangkok, Manila, Djakarta, Rangoon or Hanoi and near the mining centres of iron, bauxite, tin, gold, copper, etc. Most of the States till now are facing a serious problem of foreign exchange resulting from an unfavourable balance of trade chiefly because of the great imports of coal and fuel oil. Only recently the great

potentialities of water power are in the process of being harnessed, but a major problem is the scanty supplies of hydrologic data. Interesting is the fact that the people of South East Asia, although possessed enough technical skill for using water for agriculture, have shown little interest in its use as power.

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POWER POTENTIALITY AND ITS UTILISATION IN
MINERAL BASED INDUSTRIES OF ASSAM

Prabir Kumar Ghosh

Abstract

In this modern era of industrial development when India is guided by national planning of industrialisation, the essential need for the development of power resources, its potentialities and its efficient utilisation are keenly felt.

In spite of the belief in many people that Assam is very far from the rest of the country and normal facilities which are required for industrialisation are not available, it is heartening to note that many heavy and small industries have come up only within last few years.

The present study is on the recent development of power resources of Assam and its utilisation in the development of mineral based industries. Power resources of the State may be used in some new industries, like the manufacturing of tanning material, asphalt roofing sheets, Hydrogenation with high sulphur Assam coal etc.

In the present study I shall discuss the development of specific oil industries of Assam and their future potentialities. Possibilities of manufacturing of new industries like calcium carbide, asphalt roofing sheets,

manufacturing of tanning material etc. will also be discussed in brief.

Power resources of Assam not only act as power generating units, but also help the industries by acting as a raw material, lubricating oil, help in working mines, in extraction of metal, help the irrigation system of the country thereby contributing to agricultural prosperity.



The development of a country in all aspects depends to a large extent upon the development of power resources, viz, coal, oil, hydro-power and recently developed atomic power. Besides her good forest areas consisting of bamboos, reeds and varieties of soft wood, Assam is also very fortunate in having all the three competing fuels i. e. coal, natural gas and oil, in addition to hydel power. The mineral resources in the form of limestone, sillimenite, fire-clay and traces of gold are worth mentioning. There are good oil bearing seeds like 'Nahar' seed which contains about 70 per cent oil. In addition to the above, Assam has got good coal reserve and this coal is ideally suited for low temperature carbonisation as it has low ash content and is highly volatile. As regards hydel-power, the Umtru Power Station which has a capacity of 7.500 Kw. has already been commissioned for the last few years and the total availaibility of the Umium phases in about 36 megawatt.

In the present study the following aspects will be discussed—

- a) Power resources of Assam and their utilisation.
- b) Development of mineral based industries, like refining of petroleum.

c) Future possibilities of a few industries e.g. asphalt roofing sheets, manufacturing of tanning material, calcium carbide and hydrogenation.

Power Resources and their Utilisation in Assam

Most important potential resources of Assam is hydro-electric power.

Hydel Power

The hills and plains, its climate, all round the flanks of Assam Valley speak for themselves. As for hydel-power, the total installed capacity nine years ago (upto 1957) was mainly from Diesel Power Station which served the purpose as a preliminary step of industrialisation. Now the total availability of power from the Umiam phases (three phases) is about 36 megawatt. With the development of another Thermal Project at Gauhati the power position has become quite easy in this area. Steps are also being taken to have the high tension lines extended to the north bank of the river Brahmaputra and upto Cachar in the south, so that powers would be available to industries in these areas.

Natural Gas

A big power station based on natural gas has been commissioned at Namrup. This power station has been started and it supplied power to the Fertiliser Corporation and other industries based on natural gas. This station has a capacity of about 100 megawatt and is also able to supply power to Tinsukia, Dibrugarh and Jorhat area. Most of the industries based on minerals and forest resources in the State get the supply of power from these two main generating stations.

Oil

Assam produces major portion of India's total mineral oil. The discovery of oil in Assam dates back to 1866 at Margherita. In 1890 Digboi became the principal field of supplying oil. A small quantity of poor quality oil is found in Makum and Lamdang in Lakhimpur and at Patharia and Masimpur in Surma Valley. Besides new oil fields have been found in Nahorkatiya and Moran which started production in 1953 and 1956 respectively with a proved total reserve of 45 million tons. Recently Oil and Natural Gas Commission made extensive surveys in the alluvial areas of Assam, and in October, 1960 an oil well was struck at Rudrasagar. The oilsands are associated with the coal measures of Eocene-Oligocene Barail series, which change laterally from hard sandstones in the Barail range itself to carbonaceous shales and coal in the north. In Assam oil mostly occurs in Tipam sandstone of riverine origin.

Coal

Tertiary coal is found in Upper Assam and in recent years large deposits have been found in Garo and Khasi Hills. The present annual production of coal in Assam is about 5 to 6 lakhs tons, and it is ideally suited for low temperature carbonisation as it is low in ash content and is highly volatile. Sulphur may be an important bi-product if it can be extracted economically.

Assam's coal resources could be used in chemical industries such as low temperature carbonisation, hydro-generation, and for producing metallurgical coke.

Development of Mineral Based Industries

In spite of many difficulties of transport and power, tea, oil and plywood have become very well established

industries in this region. Assam oil fields are the major supplier of crude oil in India and meets substantial portion of the country's demand of petroleum products. It is worth mentioning that Assam Oil Company produces about 0.50 million tons of petroleum products and Indian Refinery Ltd., Gauhati, refines 0.75 million tons of petroleum. Out of these, wax is a good foreign exchange earner and all the others conserve foreign exchange by meeting the local demands.

Mineral based industries can be grouped as follows :

1) *Oil India Limited* : It is formed as a result of an agreement between the Government of India, the Burmah Oil Company Ltd., and Assam Oil Company Ltd., for developing the field in Assam which was originally discovered by A. O. C. Ltd.

The main objectives of the Company are exploration, prospecting minning and transporation of crude oil. It has already started production and pumping out crude oil by pipe lines to the refineries at Gauhati and Barauni. Oil India is also producing nearly 75 m. cft. of narural gas for thermal plant and Fertiliser Corporation of India Namrup and for distribution to tea estates and other petro-chemical industries like Acrylic fire, carbon black etc.

2) *Indian Refineries Limited, Gauhati* : It produces petroleum, kerosene, diesel oil, Iomax, petroleum coke and fuel oil. Its capacity is 75 m. tons a year which is likely to be increased.

3) *Assam Gas Company* : This unit supplies gas to upper Assam area through pipe lines for industrial and domestic consumption.

4) *India Carbon Ltd., at Noonmati, Gauhati* : A private enterprise, is manufacturing calcined petroleum coke. It has gone into production by the latter part of 1962. The capacity is 30,000 tons per year.

5) *Thermal Project* : A thermal project by the Assam State Electricity Board at Namrup based on natural gas from oil fields has started power supply by the early part of 1964. The total power generated is nearly 90 megawatt.

6) *Cement Factory at Cherrapunji* : A long expected cement factory at Cherrapunji has now been started. The capacity of this factory now is about 300 tons per day with an expansion scheme of 600 tons a day. Another factory at Bokajor would start within a very short period.

7) *Fertiliser Corporation of India Ltd.* : Based on natural gas available at Naharkatiya, a fertiliser plant at Namrup is being set up with a capacity of—

Ammonia	66,000	million per year
Sulphuric Acid	82,500	„ „
Ammonium Sulphate	1,00,000	„ „
Urea	55,000	„ „

The power requirement of 14,000 Kw. is supplied by the thermal power station of Assam State Electricity Board.

Future Possibilities of Industries Like Asphalt Roofing, Calcium Carbide, Tanning Material and Hydrogenation

i) *Asphalt Roofing sheet*) : There is a great scarcity of roofing material in Assam. Manufacturing of asphalt roofing sheets may be a good industry. The roofing material for Assam should be light in weight, easily movable, suitable for the high rainfall of the locality and at the same time economical. The main materials required for this project are—

a) Hessain fabrics b) Bitumen c) Mineral granule and aluminium sheets.

1) Hessain production in India is about one million tons per year.

2) Bitumen is available in plenty in the country. Assam Oil Company produces Bitumen about 1000 tons per year.

3) As regards minerals there is no shortage in India.

ii) *Calcium Carbide Industry*: Assam has abundant deposits of limestone and coal. With the availability of electricity a carbide industry in the State can be easily established. Acetylene is another important industry which may also be integrated with the carbide industry. Acetylene is the most important basic raw material for making plastics, synthetic fibre, rubber and various other chemicals.

iii) *Manufacturing of Tanning Materials*: Vegetable tanning materials, non-edible oil seeds like Nahar or Nageswar, resin etc. are found abundantly in Assam. There are still enough potentialities in the state to develop the resources, since India as a whole is still deficient in these raw materials. Wattle plants which are very rich sources for supplying vegetable tanning materials grow at an elevation of 1200 metres to 2100 metres. The experimental plantations have been successful in Shillong and Kohima area. It has also been found that these plants contain more tanning materials than those grown elsewhere in the country.

iv) *Hydrogenation*: It has been observed that Assam Coal with high sulphur content is very suitable for liquid phase hydrogenation for producing coal chemicals. The percentage yield of tar acids and total oil is also much more than of other Indian varieties. It can be used in blending with Bihar and Bengal coal for producing metallurgical coke.

It is also worth mentioning that Assam has a good climate throughout the year which is helpful for industrial production. The climatic condition of Shillong shall be ideal for Electric and Precision Industries. The maximum temperature

in the State seldom attains 38°C. At the moment the affluence problem is practically non-existent. Water is available in plenty irrespective of site. In most places abundant industrial labourers are available.

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POWER DEVELOPMENT AND ITS GEOGRAPHICAL
IMPLICATIONS

Bikash B. Basu

Abstract

In developing countries the policy of 'Man's adaptation to nature' should be replaced by the policy of 'Man's adaptation of nature'. In developing countries the economic processes of production, distribution and consumption should depend on the efficient functioning of the process of conversion of the geographic realities of the environment as a source of energy. Here are some of the principles of conversion of energy resources of the geographic environment in the context of planned economy in relation to the development of power resources : (a) All available sources of energy should be harnessed and power made available in usable forms on the basis of power evaluation of the geographic environment (solar energy ; wind power ; hydro-electric power ; tidal energy ; cosmic energy ; sea-temperature power scheme ; atomic energy ; petroleum, natural gas, power alcohol and coal. (b) The location of electric power production centres at the centre of gravity of the loads. (c) No multiplication of power production units attached to industrial plants. (d) The determination of optimum length of electric power transmission lines. (e) The decentralisation of industries to be linked with the planning of power generation by harnessing the

multiple power resources of the geographic environment. (f) The supplementation of rural economy. (g) To increase the efficiency of regenerative agriculture. (h) To increase the productive capacity and lower the cost of production of agro-industrial activities. (i) The electric power to assist the processing of agricultural raw materials for conservation. (j) Energy resources are not to be developed on competitive basis. (k) The processing of energy resources to increase the power potential of the State. (l) The policy of conservation of exhaustible resources. (m) The utilisation of inexhaustible power resources lowers the cost of power generation. (n) The oil resources to be utilised only for the internal combustion engines of transport vehicles. (o) The layout of regional and inter-regional electric grid system. (p) The removal of geomedical problems of air pollution. (q) Military vulnerability of power station. (r) Maximisation of power development to meet the demands of expanding human population.



In developing countries the policy of 'man's adaptation to nature' should be replaced by the policy of 'man's adaptation of nature'. It is the animal life and plant life study in the context of the geographic environment that builds up the concept of adaptation to nature. The underdeveloped human society with lack of scientific technology is unable to modify the geographic environment or utilize the geographic environment to achieve their objectives and it conducts its human activities in the cultural, economic, political and military spheres by maintaining adaptation to the geographic environment. In the cultural field the evolution of the philosophy

of fatalism has been in response to the vagaries of climate. Aggressive military activities of nomadic tribals can be interpreted as human response to geographic environment.

In developing countries the economic processes of production, distribution and consumption should depend on the efficient functioning of the process of conversion of the geographic realities of the environment as a source of energy. Here are some of the principles of conversion of energy resources of the geographic environment in the context of planned economy in relation to the development of power resources :

(1) All available sources of energy should be harnessed and power made available in usable forms on the basis of the power evaluation of the geographic environment. In this sense the geographic environment is to be considered as the total source of energy which is to be seized and converted into usable forms. (a) The sun batteries can harness the direct rays of the sun for conversion into electrical energy (5,000 h. p. per sun-acre). The power evaluation of the solar energy diurnal and seasonal variation of a specific region will help the determination of the quantum of power available and it would also lead to the adoption of technology for the efficient harnessing of solar energy and its utilization in specific economic activities. (b) With aerofoil blades wind energy can be harnessed for the generation of electric power. Due to the variation of wind velocity, diurnal and seasonal, accumulators are utilised to provide a specific quantum of electric current. Power evaluation of wind velocity in India indicates that the coastal areas at least have the best opportunity to harness the wind energy. In the mountain sectors also there is good prospect of harnessing the wind energy. (c) The development of hydro-electric power by harnessing of running water depends on the cusecs of water flow. In the mountain sector the steep gradient of water flow will provide hydro-electric power generation inspite of small quantum of water flow. In the lowland sector, a large

quantum of water flow of inland water bodies can provide hydro-electric power inspite of low gradient of water flow. The power evaluation of the geographic environment in the context of hydro-electric power potential requires the consideration of the factors affecting the seasonal regimen of water bodies. The snow survey in the Himalayan sector, the pre-monsoon thunderstorm precipitation, the monsoon precipitation, the post-monsoon thunderstorm precipitation, frontal precipitation, tropical cyclonic precipitation, retreating monsoon precipitation determine the quantum of water flow in different parts of India. A geological survey of porous and impervious rock surface in different parts of India will determine the quantum of water flow. The interlink of inland water bodies of India through canals will remove the problems of floods and drought in different parts of the country and will improve the prospects of hydro-electric power development. A survey of longitudinal profile of rivers will help the determination of the location of waterfalls and the prospect of building up artificial waterfalls and the sites of natural and artificial waterfalls can be the hydro-electric power generation centres. A survey of cross profile of rivers will help the determination of the location of building reservoirs behind dams and the dam-sites can be the hydro-electric power generation sites. Controlled discharge of water is of great significance in the functioning of hydro-electric power generation. Apart from building dams and reservoirs, the layout of interlinking canals for inland water bodies will ensure the controlled discharge of running water. (d) The tidal energy in the estuaries and deltas can be harnessed for the generation of hydro-electric power. This technology has been developed in France. (e) The harnessing of cosmic energy for electric power generation can be located at high altitude in the Himalayan sector. (f) A survey of the prospect of utilising the difference of temperature between the lower depths and the surface of the tropical seas for the generation of electricity should be conducted on the lines of the Claude Sea Temperature Power Scheme. (g) The development of

atomic energy power in those parts of the country where the other power resources are not locally available should be taken up. (h) The utilisation of petroleum, natural gas, power alcohol and coal for the generation of electrical energy should be considered as exhaustible sources of energy while planning power development.

(2) The location of electric power production centres should be the centre of gravity of the 'loads' on the distribution system. In the context of low cost of power distribution and efficient functioning of transmission lines this power generation location policy is very important. In those parts of the country where the industrial activities and other economic conditions indicate a large demand of electric power load the location of power generation centre can be worked out by plotting all the main load centres with their maximum hourly demand in KVA and by taking moments first about a north to south axis and then along an east to west axis or alternatively from some other arbitrary datum lines. It is usually desirable to work in miles and KVA and assume 1,000 KVA to equal the power unit :

$$\text{Position of CoG : } \frac{\text{Sum of moments}}{\text{Total loading}}$$

$$\text{Moments about OY} \bar{y} = \frac{A_a \pm B_b \pm C_c \pm D_d \text{ etc.}}{A \pm B \pm C \pm D, \text{ etc.}}$$

$$\text{Moments about OX} \bar{x} = \frac{A_{a1} \pm B_{b1} \pm C_{c1} \pm D_{d1}, \text{ etc.}}{A \pm B \pm C \pm D, \text{ etc.}}$$

Substituting figures, we have

$$\begin{aligned} \bar{Y} &= \frac{(10 \times 2) \pm (2 \times 5) \pm (2 \times 10) \pm (5 \times 3) \pm (10 \times 10) \pm (5 \times 5) \pm (5 \times 5) \pm (5 \times 9)}{10 \pm 2 \pm 2 \pm 5 \pm 5 \pm 10 \pm 10 \pm 5 \pm 5} \\ &= \frac{285}{54} = 5.28 \text{ miles from OY} \\ \bar{X} &= \frac{(10 \times 15) \pm (2 \times 15) \pm (2 \times 15) \pm (5 \times 12) \pm (5 \times 8) \pm (10 \times 10) \pm (10 \times 5) \pm (5 \times 2) \pm (5 \times 5)}{10 \pm 2 \pm 2 \pm 5 \pm 5 \pm 10 \pm 10 \pm 5 \pm 5} \\ &= \frac{495}{54} = 9.2 \text{ miles from OX.} \end{aligned}$$

In those parts of the country where economic evaluation of the geographic environment indicates the possibility of the

development of economic progress with the availability of electric power the location of electric power generation will depend on the harnessing of local power resource and the centre of gravity of the 'load' will be worked out by planning the location of economic activities, agro-industries, mining industries, small scale industries as also large-scale industries.

(3) Multiplication of power production units established by industrial plants in the case of thermal power stations utilising coal or oil instead of consuming electric power from the centre of gravity of power generation centre implies criminal loss in terms of capital investment, machineries, plant-space, running cost, depreciation, fuel consumed, etc. In developing countries there is a large percentage of power generation centres attached to specific industries.

(4) The optimum length of the electric power transmission line should achieve the objectives of maintaining thermal efficiency and reduction of capital cost. In India the hydro-electric power stations located near dam sites and the thermal power stations located near coal mining areas have to transfer the electric power over hundreds of miles due to the lack of harnessing of the other power resources based on the evaluation of the geographic realities.

(5) The decentralisation of industries linked with the planning of power generation by harnessing the multiple power resources of the geographic environment of different parts of the country should have the undermentioned objectives : (a) In this phase of history of strategic bombing of economic core areas to remove the military potential of the adversary the decentralisation of industries is of vital significance in getting rid of the danger of military vulnerability. The concentration of industries along the politically sensitive international border based on the availability of huge quantum of electric power due to the location of large coal basins also bring about military vulnerability of the State. (b) The flexibility in the planning and organisation of productive activities in all parts of the country based on the

availability of electric power is of great significance in the context of removing political sensitivity. In this phase of history the adversary organizes cold war on the economic and political front to achieve the political objective. The decentralisation of industries and other economic activities help the achievement of emotional integration of the different parts of the State. The lack of prospect of decentralisation of economic activities remove political stability of the State and the adversary can take advantage of this political sensitiveness to organize cold war. Thus, harnessing of the power potential of the geographic realities of the different parts of the country should consider the socio-economic and socio-political objectives of the State to remove political sensitivity and military vulnerability.

(6) The supplementation of rural economy by fostering small scale industries can be achieved by providing electric power in the rural sector. A developing country like India which has an international reputation for the quality of its handicraft products will build up a revolutionary increase of its Gross National Product in case the small scale industries in the rural sector are progressed by the provision of electrical power.

(7) To increase the efficiency of regenerative agriculture of developing countries in the context of population explosion the provision of electrical power in the rural sector is of great significance.

(8) To increase the productive capacity and lower the cost of production of agro-industrial activities, the planning of the harnessing the electric power-potential of the geographic environment is of great significance. Due to non-availability of electric power in the rural sectors of India the agro-industrial centres have to establish power generation centres by obtaining the supply of coal or oil over vast distances and the cost of production of sugar and other industrial

products reaches higher than the world market prices. In other cases, the raw materials of agro-industrial activities have to be transferred to urban centres where electric power is available which lowers the production potential based on the quantum of raw material available. Some of the exhaustible raw materials deteriorate due to this transfer from the production area to the industrial base.

(9) After the harvesting of crops and fruits the availability of electric power in the rural areas will provide the prospect of pursuing the policy of processing the materials for conservation. After the achievement of conservation processing the materials can be transferred to the whole country as also the world market throughout the year. This will increase the economic return of the raw material and raise the economic progress of the rural population. It would also remove the danger of loss of large quantum of products due to deterioration.

(10) Energy resources are not to be developed on competitive basis. The harnessing of energy resources should be based on (a) the power evaluation of the geographical realities of the exhaustible and inexhaustible energy resources in specific regions ; (b) the technical aspect of the demand for the type of energy resource and the quantum of power in specific productive activities like electro-metallurgical industries, electro-chemical industries ; (c) the technical problem of particular users of energy resource demanding certain physical and chemical properties in fuel to be satisfied for reasons of ultimate economy as in the case of ceramics needing high ash coal but the power station needs high volatile low ash coal.

(11) The processing of energy resources increases the power potential of the State : (a) The destructive distillation of coal and pulverisation of coal increases the availability of very much larger quantum of power as compared to the utilization of solid fuel ; (b) the utilization of low grade fuels like lignite in pulverised or briquette form increases

the power potential of the solid fuel ; (c) production of power alcohol from molasses in the sugar cane cultivation areas and from the starch yielding food grains will raise the power potential of the State.

(12) The developing countries should pursue the policy of conservation of exhaustible sources of electrical energy like coal, oil and natural gas. The planning of the utilization of these resources on a long term basis will remove the charge on the society to exhaust the capital inheritance like a drunken heir on a spree.

(13) Cheap electric power generation depends on the utilization of the inexhaustible sources of energy provided by nature and this assists the utilization of certain minerals and certain productive activities. In general, the cheap electrical power generation by harnessing the wind power, solar energy, hydroelectric power, and other sources depending on the geographical environment, will raise the economic potential of different parts of the State and shift the centre of gravity of the economic core areas.

(14) The development of the internal combustion engines and the increasing use of this for transport vehicles over the land, sea and air, and for driving stationary machinery as well has increased the significance of preventing the use of mineral oil for electric power generation. The mobility of the armed forces depends on the availability of mineral oil in the context of tactical and logistic operations. The functioning of air power and sea power is also vitally linked with mineral oil. A country dependent on imported mineral oil can face a security crisis during a political and military emergency in case the supplier imposes restriction on the flow of oil to enforce a specific line of action. A developing country having the mineral oil resources should pursue the policy of utilizing the oil resource for the functioning of internal combustion engines of transport vehicles and prevent the use of mineral oil for electric power generation and stationary machinery. This is possible only when the

harnessing of the power resources of the geographic environmental realities is multiplied.

(15) In a developing country like India the vagaries of monsoon create a crisis of hydro-electric power supply. The rainfall may be very much below the average in specific year. On the other hand, one part of the country may be a victim of floods while in the same year another part of the country may be drought affected. The shortage of water enforces the lowering of electric power supply from hydro-electric power stations for a large part of the year. The State should pursue the policy of fixing the layout of regional electrical grid system as per the following pattern: (i) controlled power flow from electric generating station A to electric generating stations B and C; (ii) controlled power flow from station B to stations A and C. In case due to the vagaries of monsoon electric power generation at station A fails to provide the normal quantum of electricity then the stations B and C can meet the demand of station A area by providing the controlled flow of electricity through the grid system. In case wind power, solar energy and hydro-electric power are harnessed, the electric power generation will suffer from regional and seasonal variability. To meet the challenge of such problems there should be regional and inter-regional electric grid system. The pattern of the grid system should be based on the power generation sources and the regional consumption load of electricity.

(16) The dependence on electric power generation of the developing countries on pursuing the policy of slavery to coal and the domination of the industrial activities by carboniferous agents create the serious geomedical problems of air pollution. In the urban and industrial areas, the smoke released from electric power stations utilizing coal for power generation is responsible for predisposition to pulmonary diseases, damaging of respiratory tracts, reduction of resistance to infectious diseases, psychological stress and strain and allergic disorders. In recent years research in the

field of cancer has disclosed that the air pollution with polynucleic hydrocarbons in urban areas has led to the increase of lung cancer as compared to rural areas. Air pollution through smoke connected with smog has been found to damage agricultural products in the industrial suburban areas by choking up the stomata of the leaves and by acid reaction. Such damages of agricultural products not only affect the economic activity but also affect the public health through the intake of damaged food source. These geomedi-cal problems require consideration while planning power resource development and application of technology. The smoke-polluted atmosphere should be considered as the environment of paleotechnic world. In this phase of neotechnic world, the developing countries like India should remove the smoke pollution of atmosphere.

(17) The location of power stations, particularly hydro-electric power stations with large dams and reservoirs of water along the international borders requires military evaluation. On the basis of hydrographic and topographic analysis, the building up of very large dams and water reservoirs for hydro-electric power development will bring about military vulnerability of the country in this phase of history when strategic weapons of destruction are deployed through air space. A number of small dams and small reservoirs of water built along the river course at a distance of a few miles interval can generate the same quantum of electricity as a high dam and large water reservoir. But in this case the prospect of military vulnerability will be reduced.

(18) The maximisation of conversion of energy resources of the geographic environment is to be linked up with the demands of the human society with expanding population to replace the concept of territorial expansionism through political and military aggressive lines of action.

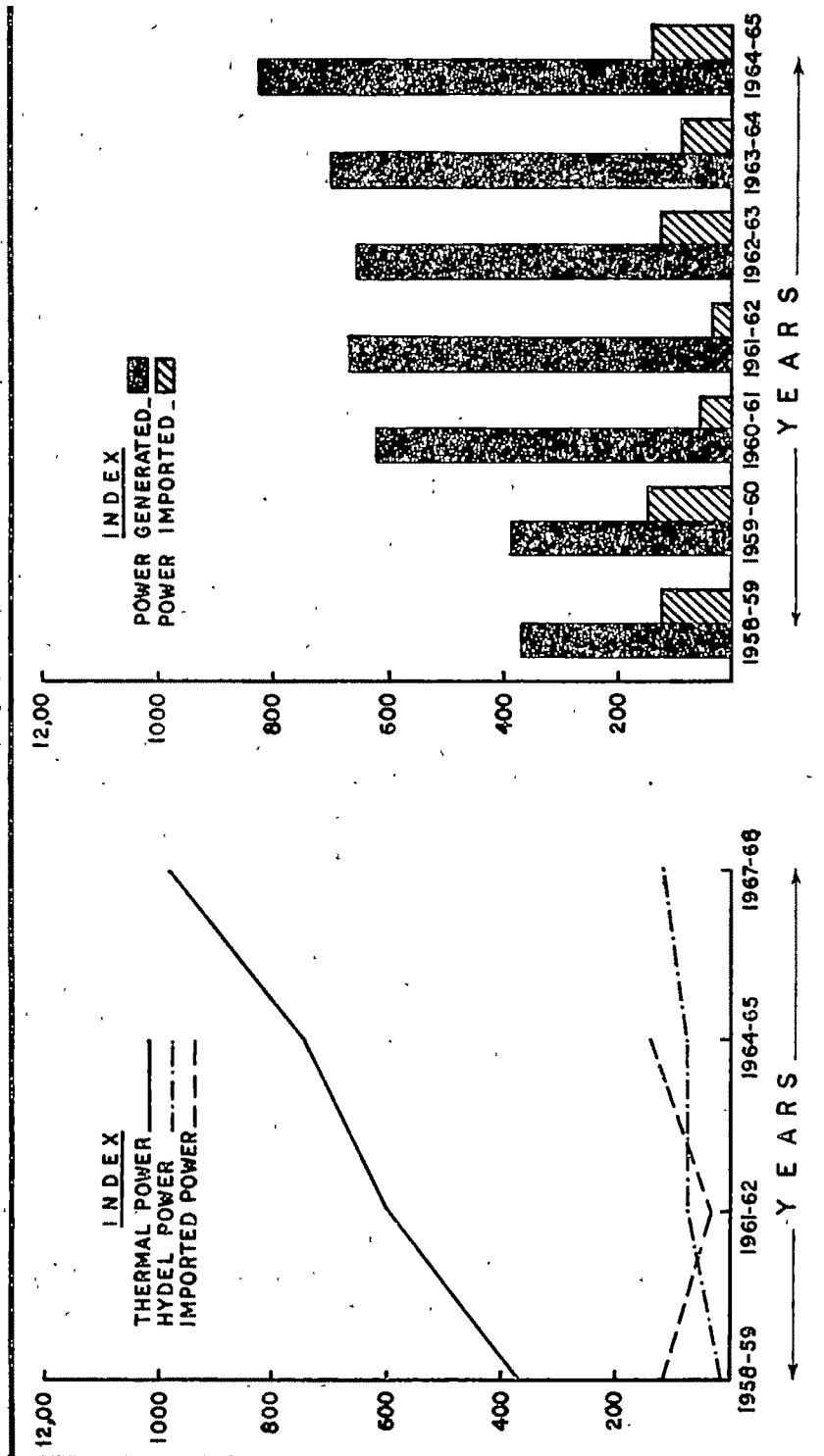
DEVELOPMENT OF ELECTRIC POWER IN WEST BENGAL

Dr. S. N. Mukherjee

Abstract

The consumption of electrical energy in West Bengal has rapidly begun to increase after independence. From no hydel power output and only slight amount of thermal power to a per capita consumption of 8.13 KWH. in domestic sector only. Since the completion of Damodar and Mor Valley Projects industrial use of power came into being and it was felt that more power must be supplied to meet the rapidly increasing demand. Hence, new thermal power plant at Durgapur was started which soon found to be inadequate and other thermal power stations had to be opened up at Bandel and Farrakka-Disergarh area. Simultaneously with rapid production and consumption of power in the southern part of West Bengal, northern part also began to hanker for power, as a result of which Jaldhaka Hydel Project, Little Ranjit Hydel Project, Bijonbari Hydro-electric Scheme and Diesel power station at Malda came into being. This rapid development of power production with still greater demand for power in the State is a healthy sign for the economy and prosperity of the State. Hence, all care must be taken to develop potential power resources and cater the power, through a network of grid to all parts of the State so that an overall progress may be seen in this part of the sub-continent.

DEMAND OF ELECTRIC POWER IN WEST BENGAL (IN MILLION WATT)



Electricity is the greatest boon in the hands of the present generation. It is most convenient to use, easy to carry from one place to another and can be generated in huge amounts according to the requirements. This can be generated by moving a field coil rapidly within a strong magnetic field. The rapidity with which the coil is moved within the strong magnetic field will determine the amount of electricity, or in other words, the amount of electricity generated is proportional to the rate of change of the 'flux'. The invention of electricity has revolutionised the entire sphere of human activity in all respects; we cannot think of a moment without electricity.

Electricity can be obtained, as mentioned earlier, by rotating a field coil within a strong magnetic field. Now, this rotation can be made with the help of steam power, diesel power or swiftly flowing water, through a turbine. Steam can be obtained by burning coal. Hence the first two may be regarded as Thermal Power and the latter one as Hydel Power. While Thermal Power generation causes exhaustion of solid or liquid fuel lying under the earth's crust and hence will come to an end at some future date, the supply of water will continue to remain, practically the same for a long time.

In India, though electricity is being used for a long time but since the independence of the country its consumption has increased tremendously. Formerly electricity was not used so largely in industry and commerce as in the post-independent period. Before independence, the generation of electricity in India and in West Bengal too was in the hands of private enterprises, but after independence it was taken over by the respective governments both in the Centre and in the States. The prospect of developing hydel power in different parts of the country attracted attention of the Government and rapidly a number of hydel power stations developed with the object of flood-control and power development. But the greatest drawback of the hydel power stations in a

monsoonal region like West Bengal is the shortage of supply of water during the dry season. Arresting flood waters in large reservoirs though ensures regular supply yet it has much limitations. As such, a number of Thermal Power stations are to be constructed to supplement the Hydel power.

In West Bengal before independence, only thermal power was produced and that too only in certain places to meet the local requirements. Even after ten years of independence the demand was less than 500 Mw. But since 1958 the demand of electricity increased four times. The adjoining table shows the gradual increase in the demand of electricity.

(In million Watt)

Year	Steam	Hydro	Oil	Total	Import	Total
1958-59	364	3	4	371	116	487
1961-62	593	68	5	666	31	697
1964-65	743	70	5	818	138	956
1967-68	1043	110	5	1153	No data	

From the above table it appears that thermal power is dominantly high over hydro-electric power and that the thermal power production has increased very rapidly. This is because of the fact that thermal power plants can be set up quickly at a lesser cost and the raw material is available near at hand. On the other hand, hydel power can be generated in large amounts in the northern mountainous area at an initial high cost and has to be carried to a long distance to the consuming centres. But to meet the rapidly increasing demand, power had to be regularly imported from outside

the State. The import of power was less at the end of the Second Five-Year Plan period. This was due to the availability of DVC power from Durgapur Thermal Power Centre and Mesanjore Hydel Power Centre. Similar jump in power production at the end of Third Five-Year Plan period is observed due to the availability of Bandel Thermal Power (300 Mw), and Jaldhaka (36 Mw) and Little Ranjit (22 Mw) hydel power plants.

According to the estimate of the Socio-Economic Survey the power requirement in the State of West Bengal may be given as follows :

Expressed in billion Kw

Year	Rural	Urban	Total
1960-61	0.010	0.579	0.589
1965-66	0.025	1.158	1.183
1970-71	0.040	2.316	2.356
1975-76	0.060	3.474	3.534

This is quite distinct from the data of the State Electricity Board, but hold a very optimistic view about the consumption of electricity in this State. Any way, it shows clearly how consumption of electrical energy in the rural and urban sectors is likely to increase, the increasing utilization of electrical energy in the rural sector is particularly significant as it has already dawned a new era in agricultural activities through the electrically operated tube wells for irrigation. More use of underground water with the help of electrical energy will improve our lot in the food front. The author, in a separate article (Mukherji, 1967), has shown how best it can be done.

From the above discussion it appears that in the State of West Bengal, inspite of increased generation of power, the power had to be imported from outside due to the fact that

demand for power has increased greatly because of electrification of railways and greater industrial, agricultural and domestic requirements. West Bengal with a vast population and advantageously situated for the development of industries and intensive agriculture is expected to need more power in future.

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UTILIZATION OF HYDEL AND THERMAL
POWER IN WEST BENGAL

Saumyananda Chatterjee

Abstract

West Bengal with its vast coal resources in the West and hydro-electric potential in the West and North is in a position to develop only small portion of its power potential. Her power consumption is the highest in India and it is rising steadily with increasing demand. Regional imbalance in the development of power energy and consumption is a striking feature in the power generation and consumption in the state of West Bengal. Peat head location of power stations and inter-State integration with grid systems and the development of practically untapped resources of the northern rivers with proper utilization of huge coal reserves of the West are some of the answers in ever increasing demand for power.

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The development of power resources in India, though a land of large rivers, has not been spectacular. Of the 40 million Kw. of hydro-electric resources in India only about 1 million Kw. of hydro-electric power have so far been developed. This development again has been mostly in south India. In West Bengal, hydro-electric schemes have made very little stride. Of the total power of 1,498.413 Kw. obtainable from various types of power stations in West Bengal only 67,088 Kw. representing near about 11.8 per cent

of the total power is obtainable from hydro-electric stations. There are only 3 hydro-electric stations out of 25 different power stations in West Bengal. The development of hydro-electric power in West Bengal has not been proceeding on par with the other States of the Indian Union. Two reasons can be advanced for this anomaly: (1) comparatively high cost of developing the water power and, (2) proximity to coal fields ensuring power supply to West Bengal at a very cheap rate.

In West Bengal, where both the hydro and thermal power resources (coal reserves 13,000 tons) are available the two sources of power may be considered as complementary rather than competitive, and ways and means should be found to develop hydro-power in this State, taking into consideration its action and reaction upon the economy of the State.

From the point of view of hydro-electric generation, the rivers of West Bengal can be classified into three groups:

Group A: The rivers of the Gangetic plains have their sources in distant mountains. The Gangetic plain being flat, the rivers of this group cannot be utilised for hydro-electricity. The Ganga is the largest of this group, draining an average annual rainfall of 107 Cm. over a catchment area of 1,029,800 sq. kilo metres with a record discharge of 2,000,000 cusecs. In the lower deltaic region, there are number of estuaries where the possibility of obtaining power from the tides may be explored. But however alluring this may be, the prospect of developing tide as a source of energy at least for the present is disappointing.

Group B: The rivers of this group are the Subarnarekha, the Cossaye, the Damodar, the Ajay, the Mayurakshi etc. They run from West to East, more or less in parallel direction. These rivers have their sources in the Chotanagpur and Santhal Parganas hills. With the advent of monsoon lasting from June to September the rivers bring in enormous volumes (average 11,000 cusecs) of water at times causing destructive

floods but during the rest of the period they run practically dry. The Damodar is the typical example causing floods during monsoon and dwindling to a mere trickle in dry season. To harness power from these rivers, dams have been constructed at suitable sites on the Damodar and the Mayurakshi. On the basis of this unified development actively executed by the D.V.C. and the State Govt. hydro power is being obtained from the above projects at a cheaper price, low enough to compare with the cost of power from other sources.

Group C: The north Bengal rivers arising from the Himalayan region bordering the north, for the most part Sikkim and Bhutan, fall under this group. The Tista and all others which flow east of it, viz. the Jaldhaka, the Raidak, the Gangadhar etc. rise from the Himalayan region and flow through the districts of Jalpaiguri and Darjeeling. These snowfed rivers with heavy rainfall in the region have great hydel power potential. But the rainfall being seasonal, the flow of these rivers vary over a wide range during the year, so that the steady power available, dependent on minimum flow, will be quite small in comparison with the size of the river, unless suitable storage basins for the water can be constructed. The landslide problem in this region, again, is a formidable factor. All of these would make the capital cost of such projects appreciably high. If, however, for the control of north Bengal flood, any scheme of construction of dams is carried out as in the Damodar, it might be possible to utilise it for power production as well. Due to remoteness of this area from the coal field the installation of thermal power plant is ruled out.

West Bengal matches its relative primacy in industrial development with a commensurate development in the field of power. Its per capita consumption of 166 Kwh was the highest for any State in India in 1967-68 and it contrasted conspicuously with an all-India average of as low as 46 Kwh only. However, domestic consumption forms a very limited

proportion of the total consumption. In the same year out of a total of 1,498,413 Kwh sold by public utilities to ultimate consumers, domestic consumption accounted for only 13.2 per cent while the industrial consumption was 4.0 per cent.

Total sale (Million Kwh)

	1965-66	1966-67
1. Domestic consumers	509	561.0
2. Commercial consumers	172.5	191.0
3. Industrial Power	2,975	3,047
4. Public lighting	29.8	32.0
5. Traction	209.3	286.8
6. Irrigation & Agriculture or dewatering	4.2	7.7
7. Public Water Works & Sewage Pumping	110.5	117.9
8. Sold to outside W. B.	38.8	6
Total	4049	4244.4

Another striking feature of the situation is the regional imbalance in power development within the State. On the one hand, Calcutta and its industrial conurbation have attained an order of development which is the highest in the whole of India and, on the other hand, in the rest of the State, facilities of electricity supply are either inadequate or non-existent. In 1966-67 about 90 per cent of the total energy consumption took place within the licensed area of Calcutta Electric Supply Corporation. The per capita consumption of 305 Kwh within this area is the highest in India. Asansol, Durgapur, Jalpaiguri and Darjeeling account for almost the whole of the regional energy consumption of the State. This regional imbalance in power development is in accordance with the regional imbalance in industrial development. Whether catering for more civic amenities, or for dispensing industries, to outlying towns or semi-rural and rural areas, it is essential that adequate facilities are created for generation and transmission of power to serve these deficient areas in addition to the present areas of supply.

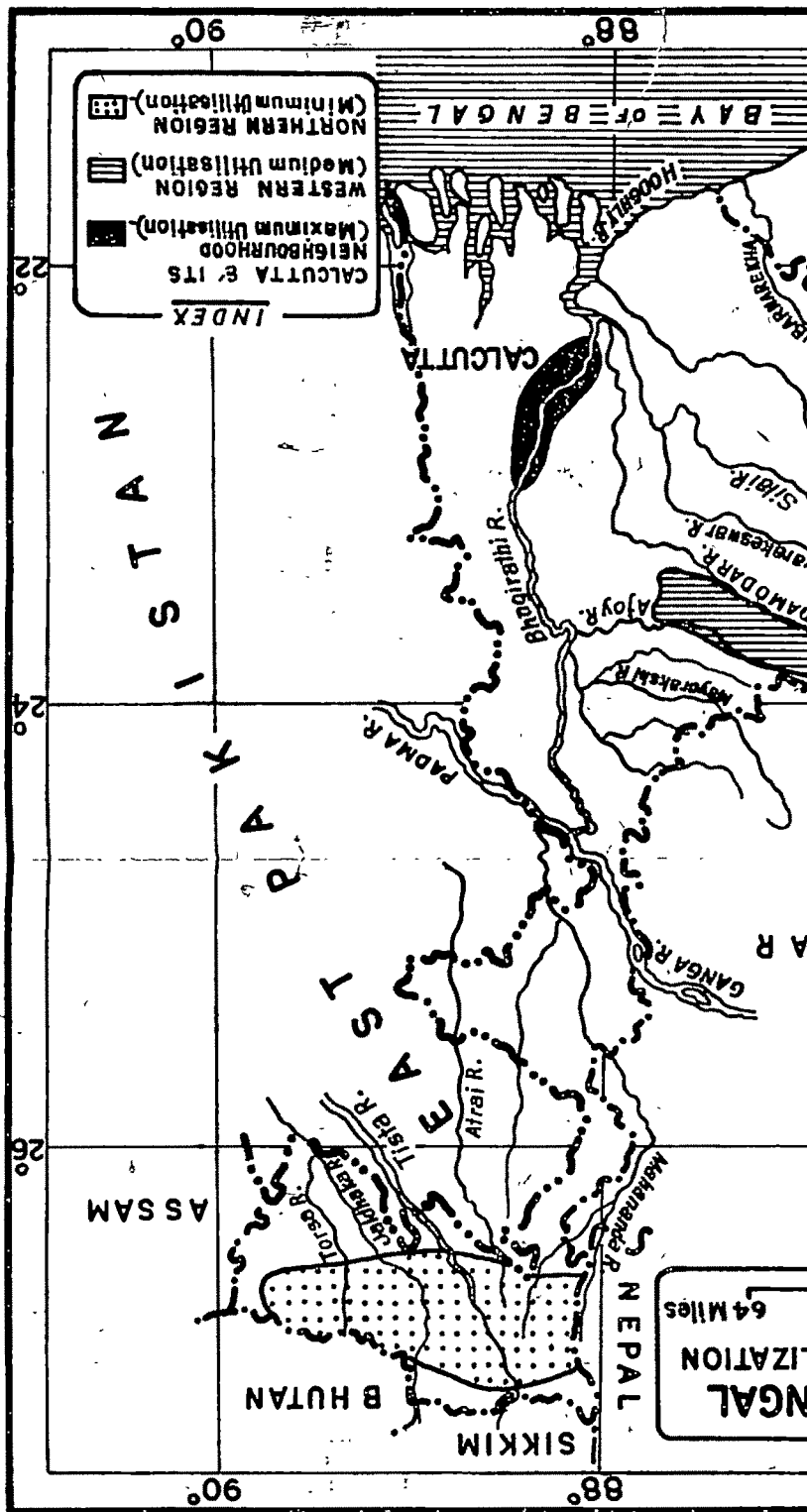
The total installed capacity in West Bengal is about 1498.413 Kw. comprising 1490.850 Kw. thermal, 10.375 Kw. diesel and 67.088 Kw. hydel stations. The total installed capacity is estimated to reach nearly 1,135 Mw. by the end of the Third Plan, mostly in thermal stations at Bandel (4x75 Mw) and Durgapur Coke Oven Plant extensions (225 Mw) with only 13 Mw from Jaldhaka hydro-electric and the rest in the private sector.

With the installed capacity of 1,135 Mw at the end of the Third Plan it will be possible to meet nearly 4.5 million Kwh of electricity requirements (4,000 Kwh of installed capacity is assumed). The balance of one million Kwh will have to be met from D.V.C. whose installed capacity at the end of the Third Plan will be 944.0 Mw comprising 104 Mw hydro and 840.0 Mw thermal. The combined capacity of West Bengal and DVC plants will be adequate to meet the demand of West Bengal during 1968-69.

To meet the anticipated demand in 1970-71 an additional installed capacity of 770 Mw will be required. The continuing schemes of DVC will yield about 140 Mw in the Fourth Plan. The second stage of the Jaldhaka Hydel scheme will yield 9 Mw in the Fourth Plan. The balance of about 620 Mw will have to be met by new schemes. At present there is no precise estimate of the considerable hydro potential of North Bengal. The Tista river basin alone is understood to have 100 Mw potential and the Jaldhaka river has a potential of 77 Mw. The Tista scheme may materialize in the Fifth Plan. The entire additional requirements for this period will have to be met by thermal generation.

During the Fifth Plan, the additional demand will be 7.13 million Kwh. This can be met by 1,000 Mw from Tista and the balance is to be met by thermal plants of 1,000 Mw capacity.

A plan can be drawn for the optimum utilization of the available sources of power. It is estimated that only 2 to 4 per cent of the total demand for power will originate in the five



northern districts. So this region can be fed from small and medium hydel stations some of which are already under construction. Calcutta and its industrial surroundings and the Asansol-Durgapur region should be served from pithead superstations. The cost of generation and transmission at such stations will be the minimum attainable. Nearness of generation to load will also keep down the operational and maintenance cost. Transmission of power to Calcutta from pithead stations is both economical and desirable compared to local generation of power with imported coal. This will relieve the burden in railways, help railway and rural electrification by providing a continuous source of power spread over the whole countryside.

Pithead thermal super stations provide economical as well as technical solution of the power problem of both the major load centres of West Bengal even if an economical proposition could supplement the thermal power only after a decade. It will be quicker to generate thermal power at pitheads than to generate hydel power in the north. However, to obtain hydro power in the Fifth Plan, work on hydro-projects should start during the Fourth Plan itself.

The DVC region consisting of the contiguous industrial regions of West Bengal and Bihar has the heaviest load concentration in the whole of India. Zonal integration as such would be economical. In such a zonal scheme power generations should be centralized at as few a stations as possible. The generating stations should be linked up with one another to reduce stand-by, to hold down the peak load by taking better advantage of diversity and to extend power facilities far and wide. A high tension grid should be erected preferably in a ring, in the main system. It will be expedient to have only one authority to rationalize the power generation and transmission in this region.

A thermal super station of 500 Mw incorporating four 125 Mw sets at pithead in the coal mines or adjacent to a coal washery is recommended.

During the Fourth Plan progressive installation of 200 Mw sets at pithead thermal super station of 1,000 Mw total capacity is recommended for showing the grid.

Scheme like Tista Project should be completed in the Fourth Plan so that construction may be undertaken during Fifth Plan to assure commissioning early.

The capacity of the thermal station at Durgapur should be increased.

The possibility of constructing an extra high tension transmission line from the hydel site in North Bengal to pass through West Dinajpur and Malda and to join the D.V.C. grid at Burdwan for feeding hydro-power may be examined when bulk generation is started.

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POWER DEVELOPMENT IN THE STATE OF BIHAR, INDIA

Rameswar Prasad Sinha

Abstract

Prior to 1948, generation of electric power in Bihar was confined only to 25 urban centres. The progress was accelerated after the creation of the Bihar Electricity Board and during the successive Five-Year Plans. Commendable contribution was also made by the Damodar Valley Corporation on completion of the hydro-electric stations at Tilaiya, Maithon and Panchet with installed capacity of 4 Mw, 60 Mw and 40 Mw respectively and the Bokaro Thermal Station with installed capacity of 75 Mw. The State has developed three thermal stations at Barauni, Chandrapura and Patratu with capacity of 200, 100 and 100 Mw respectively and has constructed a 132 kV line for supplying power to the railway. At the end of the Third Plan period the installed capacity of the State Board was 545 Mw. Based on the load survey conducted by the Bihar Electricity Board in 1963, the demand for electricity is estimated at 333 Mw for North Bihar and 1359 Mw for South Bihar and Chota Nagpur by the end of the Fourth Plan. Due to zonal grid and integrated operation of the power systems of the neighbouring States, the Central Water and Power Commission suggested schemes for an additional installed capacity of 1230 Mw for meeting the future demand.

Construction of thermal power stations at Tenughat, Ray, Bhojudih and Giridih, and hydro-electric stations on the Gandak, Kosi, Sankh, Kanchi, Ghagra and North Koel rivers may be suggested in the subsequent plans to meet the rising demand for power due to rapid industrialisation.

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The rapid industrialisation, modern mining technique, efficient commercial operations, new method of communications, development of lift-irrigation, electrification of railway tract, urban and rural centres are primarily dependent on power production of the State. It has enormous power-potentiality in the form of coal, water-resources and atomic minerals. Recent explorations give hopes for oil reserves in North Bihar. The State has started the work of harnessing its resources for power development.

Approximately half of India's coal, i.e. nearly 32 million tonnes, is mined in Bihar. There are in all twenty-one coal-fields—three in Dhanbad, seven in Hazaribagh, three in Palamau and the rest in Santhal-Parganas districts. According to the Geological Survey of India, the total reserves of good coal in Bihar are estimated nearly 6,000 million tonnes up to the depth of 400 metres. These coal fields provide coal for thermal power production.

A survey on water conservation was conducted by the Bihar Government in 1955, which shows that the average annual yield of water is 45 million acre-feet and 40 million acre-feet¹ in North Bihar and South Bihar including Chotanagpur Highlands respectively. Large catchment basins of the snow-fed Himalayan rivers, like the Kosi, the Gandak, the Burhi Gandak, the Kamla, the Balan and others, with high rainfall, account for high average yield of water in North Bihar. The rivers of Chotanagpur Highlands descend

across steep-scarps and winding 'ghats' having source-regions on the plateaus of varying elevations. High periodic rainfall increases the capacity of water in rivers at fall sites and provides opportunity for conservation of water-power. The estimated hydro-electric potential of the State is 61,000 Kw.²

The Department of Atomic Energy has established the Uranium Corporation of India for exploration and production of atomic minerals in India. Ores of uranium occur in Bihar along the copper-belt of Singhbhum and contain 10 to 40 per cent uranium. The Corporation has set up a chemical processing plant at Jadugoda, while ores are mined in Bhilai Pahari and Bhatin area. In near future, atomic minerals will provide considerable amount of power to Bihar.

In spite of its rich power-potentiality, however, the State has lagged behind in power development. This is evident from the fact that electricity accounts for only 7 per cent of the total energy consumption in the State as against about 12% in West Bengal, 11% in Madras, 10% in Maharashtra and 8% in Punjab and Mysore and the per capita consumption of electricity recorded at 56.23 Kwh in 1966-67 as compared to all-India 70.84 Kwh.³ Moreover, a great bulk of the power generated is consumed by the large scale industries and railway traction and a small amount is left for irrigation, household industries, commercial and other purposes.

Prior to the Independence, the development of electricity in Bihar was restricted to selected urban areas under the management of private electric supply companies. They had their own generating stations, which contributed to the major power production of the State. Besides these, a few industrial concerns like the Rohtas, the TISCO, the Indian Aluminium Factory, Muri; the Indian Copper Corporation, Ghatshila; the Portland Cement Factory; Japla and Sugar production centres had also their own power generating plants. The installed capacity of the public supply concerns was 39.3 Mw., but the State Government had only 5.6 Mw.⁴ The self-generating industries had an installed capacity of

168.8 Mw. Among the large power stations owned by the industrial concerns, the power stations of the TISCO and the Rohtas had capacity of 120.5 Mw. and 12 Mw. respectively.⁵ In 1944-45 the Electricity Department of the Government of Bihar had launched the first scheme of electric supply in the Dehri-Sasaram area primarily for running the State tube-wells. A similar scheme was introduced in 1946 in Patna-Bihar-Bihra area. This was the beginning of the rural and urban electrification through state agency.

Soon after reorganisation of the Electricity Department of Bihar in 1948, the Government realised the multiple significance of electricity in the fields of agriculture, mining, industries, communication etc. and thereby started generation, transmission and distribution of electrical energy in the State. The State Electricity Department spent approximately Rs 30.54 lakhs before the execution of the First Plan. It had constructed 320 Kms of low tension lines for feeding 2400 consumers and 110 tube-wells. Before the first plan, the State had installed capacity of 47000 Kw and the per capita consumption of electricity then was 17.29 units.

The planning era begins from 1951 and both the State and Central Governments have been developing hydro-electricity, thermal power and small diesel power production sets, scattered throughout the State. Considerable progress was made by the DVC by completing installation of 4 Mw at the Tilaiya Hydel Power Project and 176.5 Mw at Bokaro Thermal Power station,⁶ which were linked with Maithon and grid sub-station at Jamshedpur. In the First Plan period, DVC had been the main agency for power production. At the end of the First Plan the Government-controlled installed capacity rose to 7 Mw (diesel station) and the length of sub-transmission lines and low tension increased from 3,200 Kms and 80 Kms respectively in 1950-51 and low tension to 4,685 Kms and 1365 Kms in 1955-56. The number of towns and villages electrified increased from 10 in 1950-51 to 364 in 1955-56. Similarly, the number of pumps energised

increased from 110 to 1253. The State Government also set up 9 diesel power stations with an installed capacity of 7 Mw.⁷ The per capita consumption of electricity rose to 29.77 units in Bihar and 26.40 units in whole of the country by 1955-56. This shows that there was an increase of 12.52 units during the First Plan period.

During the Second Plan, the Bihar State Electricity Board was constituted in 1958. It arranged for the supply of a much larger quantity of power from Damodar Valley Corporation, but the demand far outstripped the supply. It immediately undertook a survey of load prospects for agricultural, mining, industrial, communication and other purposes throughout the State. This necessitated the Government to build its own generating capacity on a large scale to meet the fast increasing demand. It, therefore, embarked upon ambitious schemes for generation of power. With the help of a Yugoslavian organisation, 15 x 2 Mw sets of the Barauni Thermal Power Plant were installed. Subsequently another set of 15 Mw has also been erected and all the three 15 Mw sets have been commissioned. The second stage of two 50 Mw sets have been erected now with help of a Polish firm to meet the demand for power in Barauni Refinery. Towards the end of the Second Plan, the State Electricity Board launched a thermal power station of 100 Mw at Patratu to cater to the needs of the Heavy Engineering Corporation, Ranchi, and other growing industries.

The Board also undertook the construction of a 132 Kv single circuit line from Maithon to Sultanganj. The total expenditure on power development schemes during the Second Plan was Rs. 19.04 crores. At the end of the Plan, the aggregate demand on the Bihar State Electricity Board's system had moved to 110 Mw from 20 Mw at the end of the First Plan⁸. This was partly met from the Board's own stations (including diesel stations) and partly fed by the power purchases from DVC, Orissa and other concerns. The per capita generation of power was 54.84 units in 1961 with

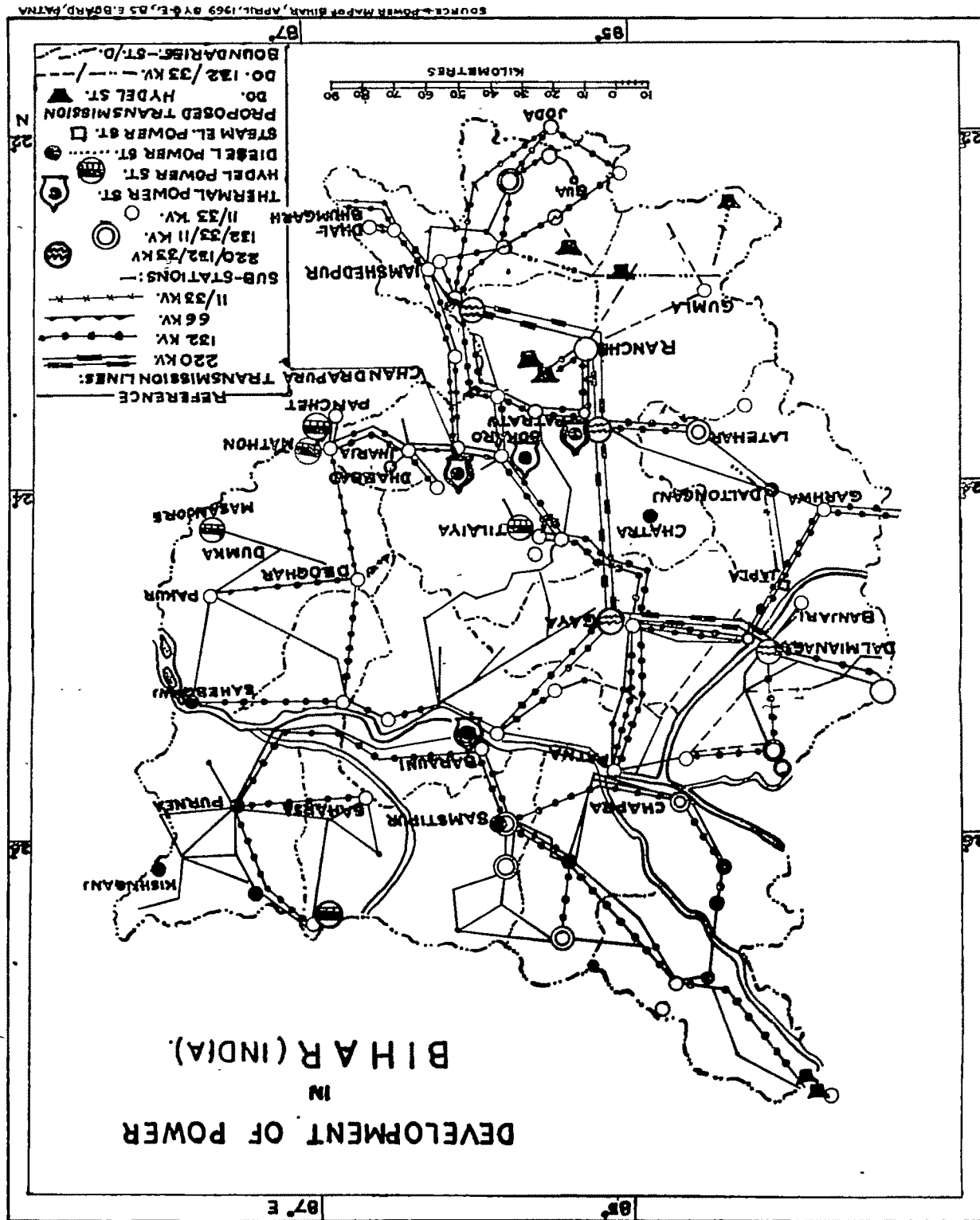
wide variations i.e. as high as 546.65 Kwh in Hazaribagh, 493 Kwh in Dhanbad, 202.15 Kwh in Singhbhum and as low as 0.05 Kwh in Gaya, 0.44 Kwh in Santhal Parganas, 1.92 Kwh in Bhagalpur and Monghyr, 2.73 Kwh in Saharsa and Purnea, 2.84 Kwh in Saran, and 3.34 Kwh in Muzaffarpur and Darbhanga. Palamau, Shahabad, Ranchi, Patna, and Champaran have 31.57, 23.80, 12.65, 9.76 and 6.24 Kwh per capita generation of electricity⁹.

The per capita consumption of power was 43.62 Kwh i.e. total 2,026,292, 674 Kwh in 1961 for whole of Bihar. Dhanbad led in per capita consumption (i.e. 612.04 kwh) and followed by Singhbhum (380.89 Kwh), Shahabad (63.34 Kwh), Ranchi (33.42 Kwh), Palamau (31.44 Kwh), Patna (30.84 Kwh), Hazaribagh (19.47 Kwh), Champaran (3.79 Kwh), Gaya (3.67 Kwh), Muzaffarpur and Darbhanga (2.74 Kwh) Monghyr and Bhagalpur (2.69 Kwh), Saharsa and Purnea (2.32 Kwh), Saran (2.20 Kwh), and Santhal Parganas (1.95 Kwh)¹⁰.

The Third Plan has executed a major portion of the present thermal and hydel power production centres of Bihar. The third Barauni set of 15 Mw and two 50 Mw sets were completed during the Third Plan. Two more sets of 50 Mw each were also approved¹¹.

An hydro-electric power station of 20 Mw on the Eastern Kosi Canal has been taken up. Another hydro-electric power station of 15 Mw on the Western Canal (in Nepal) of the barrage across the Gandak at Bhaisalotan has also been initiated¹².

The Bihar State Electricity Board undertook a survey of the State's requirement of power by the end of the Third Plan period. It was decided that the entire quantity of power required outside the Damodar Valley would be generated by the Board. Both the State and Central Governments agreed to expand the thermal plant at Patratu and approved two more sets of 50 Mw and two other sets of 100 Mw. The



SOURCE: POWER MAP OF BIHAR, APRIL, 1969 BY E.E., D.S.E. BOARD, PATNA

“Machinexport” of the USSR, which had earlier offered to supply two 50 Mw sets also agreed to supply the additional approved above sets.

The foundation of the Patratu Thermal Plant was laid on the 13th. February, 1963 and the first 50 Mw set was commissioned in about 38 months. Four Units of 50 Mw each and two units of 100 Mw each were sanctioned. By this time, the demand for power in the areas outside the Damodar Valley was assessed at 350 Mw. The Government of India and Bihar State Electricity Board, therefore decided to instal two other units of 200Mw each. Subsequently, the total installed capacity of the power station was further raised from 400 Mw to 800 Mw¹³ in order to appease the growing thirst of power in the area.

The site of Patratu Power Station is primarily based upon requirements-availability of abundant coal, water, adequate land and facilities of transport and communication. The central location of Patratu in the multi-mine—enforested territory of Chotanagpur acts as an admirable asset. The richness of Damodar Valley coal fields and the guarantee of needed water supply by the Nalkasi River, a tributary of the Damodar further added advantage to its selection for Thermal Power Station.

During the Third Plan, the Board constructed a 132 Kv double circuit line from Barauni to Muzaffarpur via Samastipur. Work on 132 Kv line from Barauni to Purnea and Samastipur to Chapra was also taken up. A 132 Kv double circuit line was laid from Patratu to Hatia for supplying power to the Heavy Engineering Corporation. Another 132 Kv double circuit line was extended to Ramgarh for linking Patratu with DVC grid. In the Third Plan, the expenditure on power programmes was Rs. 94.05 crores to meet the total demand which had gone up to 243 Mw. The Board increased its capacity by 59 Mw. The length of transmission lines increased

to 964 kms. and those of sub-transmission and low-transmission lines increased to 18,855 and 11,545 kms. respectively with 3,990 villages & towns electrified and 10,556 pumps energised. The per capita consumption rose up to 56.22 units in Bihar and 70.84 units in India¹⁴. The State lagged behind during the Third Plan period.

In the year 1965-66, power consumption in different major industries are recorded at 1,831.699 m. Kwh i.e. 17.860 m. Kwh in aluminium, 18.604 m. Kwh in chemical, 272.234 m. Kwh in collieries, 22.112 m. Kwh in copper, 1.177 m. Kwh in cotton textiles, 410.427 m. Kwh in fertilisers, 629.261 m. Kwh in iron & steel, 12.203 m. Kwh in jute, 18.957 m. Kwh in sugar 149.132 m. Kwh in engineering industries and 279.732 m. Kwh in others. It means industries consumed 74.9% of the total production of power in the State.¹⁵

The Railway traction had consumed 16.1% of the total power production in 1965-66, whereas domestic consumption reached up to 2.9%, commercial lighting 2.8%, public lighting 0.2% irrigation 1.6% and public water works 1.5%.¹⁶ The above figure shows the poor consumption in domestic, irrigation, agriculture and for other commercial purposes.

In the period of the annual plans 1966-69, the outlay on power schemes is estimated to have increased further by Rs. 59.19 crores. The installed capacity of the State Electricity Board's generating stations is increased to 313 Mw. In this period, the length of transmission lines has gone up to 2,372 kms. including 220 Kv from Ramgarh to Dalmianagar & from Ramgarh to Chandil and those of sub-transmission and low tension to 27,800 and 23,678 kms respectively.¹⁷ The number of towns and villages electrified are said to have increased to 7,626 and that of pumps energised to 51,625. It is true that rural electrification programme in this period expanded considerably to meet the challenge of unprecedented drought in 1967.

In the Fourth Five Year Plan (1969-74), the BSEB have a total programme of Rs.144 crores from different agencies.

Of this, Rs.43.31 crores would be spent on generation schemes, Rs.25.19 crores on trunk transmission, Rs.25 crores on sub-transmission and Rs.50 crores on rural electrification schemes.

The generation schemes include the expansion of the Barauni and Patratu Thermal and the Kosi & Subarnarekha Hydel Power Stations. The schemes, when completed would have installed capacity of the Barauni 145 + 120 Mw, the Patratu 600 Mw, (the rest 200 Mw in the Fifth Plan period), the Kosi 10 Mw, the Subarnarekha 130 Mw totalling 905 Mw. By the end of the Fourth Plan transmission and sub-transmission length, are expected to increase by 3,583 Kms, and 35,190 Kms. respectively.¹⁸

The State has carried out a detailed survey of power demands to meet the power shortage during the Fourth and the Fifth plans. According to the preliminary report, the Chief Engineer, Project, observed that "the establishment of four major power stations, one each at Tenughat, Ray, Giridih and South Koel would end the State's power famine".¹⁹ The North Karanpura 500 Mw Thermal station is to be executed in near future to meet the growing demand in the State. The four proposed major projects would have about 2200 Mw capacity, but this target would be achieved in phases. The proposed capacity of these projects are as follows: Tenughat 650 Mw, Ray 650 Mw, Giridih-750 Mw, and South Koel 100 Mw²⁰. Meanwhile the Board was also studying the possibilities of establishing mini-hydel power schemes suitable for village electrification. The scheme envisages drawing of power from small rivers and canals.

The power supply conditions in North Bihar, having 51,000 square kms. and 21 million people, is not satisfactory. During the Fourth Five Year Plan, this sector may have Barauni-145 + 120 Mw, Kosi-10 Mw, and Gandak 5 x 3 Mw totalling 290 Mw, which would be insufficient to meet the growing needs of industries, communications, rural & urban electrifications. Another Thermal Power station is being planned for future demand due to improved means and

methods of transportation of coal from Chotanagpur. Transportation of pulverised coal through pipe-lines is also possible. The authorities concerned should take immediate steps to connect the whole area with transmission, sub-transmission and distribution lines which should be further connected with State Grid and the Country Grid System to ensure regular supply.

The Kosi Hydel scheme consists of 4 units of 4.8 Mw each. The work is in progress and units are expected to be commissioned in the Fourth Plan period. Half of the power generated from the Kosi will be marked for supplying to the Government of Nepal and its other half will be available for its distribution in Bihar. Bihar, therefore, will receive 10 Mw of the installed capacity²¹. It will also be interconnected with Barauni Thermal Power station with a 132 Kv line at Purnea.

The Gandak project includes the construction of a barrage at Valmikinagar in Nepal, canal systems on either side of the Gandak with a hydro-electric power house. The hydel power houses on the Gandak canal will consist of 3 sets of 5 Mw each. These units will be commissioned by December 1970, April 1971 and June 1971 respectively.

The Tenughat Dam project has been planned as a storage dam at Tenughat on the river Damodar to supply industrial and domestic water to serve the Bokaro-Sindri region. It consists of two power stations, one on the up-stream side of Tenughat dam with an ultimate capacity of 1500 Mw and the other on the down-stream side of the dam with an ultimate capacity of 500 Mw.

The barrage on the river Son at Indrapuri about 7 Kms up-stream of Dehri would be provided with two power houses. Left bank Power House with installed capacity of 2700 Kw and the Right Bank Power House with installed capacity of 1430 Kw would feed the neighbouring areas.

The Subarnarekha Hydel Project 2 x 65 Mw has already been approved by the Central Government. The plants will

be supplied by M/s Bharat Heavy Electricals, Hardwar. This power station may be commissioned early in the Fifth Plan. It will be interconnected with Patratu system at Hatia.

The South Koel Hydel Project is planned to be erected on the South Koel at Basia with installed capacity of 15 Mw and the Karo at Nichitpur and Lahajimi with installed capacity of 200 Mw of four proportionate units. The third dam on the Karo is also in the offing. It may be erected on it 32 Kms below the Karo No.2 with an installed capacity of 28 Mw.

The Sankh Project comprises of the Upper Sankh Reservoir, Lower Sankh Reservoir and Lifting Reservoir with installed capacity of 20+300 Mw. 250 Mw, and 60 Mw respectively.

A load survey was conducted by the Bihar Electricity Board in the year 1963. "The demand for power at the end of the Fourth Plan was estimated as 333 Mw in North Bihar, 921 Mw in South Bihar and Chotanagpur outside the valley and 438 Mw in South Bihar and Chotanagpur inside the valley."²⁹ In view of the proposed establishment of the zonal grid and integrated operation of the power systems of the neighbouring States, the Central Water and Power Commission suggested an installed capacity of only 1775 Mw for meeting the increasing demand. It is expected that an additional installed capacity of the Board by the end of the Fourth Plan may reach 1230 Mw.

The Damodar Valley Corporation plays an important role in the history of the power development in the country. The multi-facet project contributes to the growth and development of power in Bihar and West Bengal. Dams have been erected on the Damodar and its tributaries to produce hydro-electricity. Thermal Power stations have also been constructed as a safety valve to the supply of power in the dry season. It was planned to generate power capacity of 559,000 Kw i.e. 375,000 thermal and 184,000 hydel.

The Hydro-Electric Power stations erected on the Damodar and its feeders are noted below :

(1) The Tilaiya Dam Hydro-electric Power Station is designed for an ultimate capacity of 6000 Kw. with three units of hydro-turbo-generators, each having a capacity of 2000 Kw

(2) The Maithon Dam Hydro-electric Power Station with three units to produce proportionately to reach its aggregate installed capacity of 60,000 Kw. It produced 65.78 Kwh. in 1966-67.^{23a}

(3) Panchet Hill Hydro-electric Power Station is designed for an ultimate capacity of 80,000 Kw., with two units of 40,000 Kw each. In 1966-67, it produced 51.39 Kwh.^{23b}

(4) The Konar Dam Hydro-electric Power Station is planned for generating 40,000 Kw of electricity, but the construction is not completed as yet.

(5) The construction of Bokaro thermal Power Station with installed capacity of 247 Mw in 1953, in addition to the hydro-electric stations in the basin was considered a necessity for "firming up" the flow of hydro-power to compensate the deficiencies caused by decreased volume of water in the basin during the post-monsoon seasons.

The increasing demand for power in the valley, on account of rapid industrial development, has compelled the authorities to instal a few other power stations at Chandrapura and Durgapur (W. B.). The foundation stone of the Chandrapura Thermal Power Station was laid down in January 1962. Its first unit of 140 Mw was commissioned in October 1964. In May 1965, the second 140 Mw unit was put into operation. The third unit of 140 Mw also started production in July '68. With the commissioning of its third generator, largest of its kind now operating in India, the total installed capacity of the Chandrapura Thermal Power Station reached 420 Mw. Further it is being extended by two more units of 120 Mw each. On the completion of this scheme in 1972, the installed

capacity of Chandrapura will further increase to 660 Mw and and the total capacity of thermal generation in the DVC system will be 1197 Mw. The contribution of Chandrapura's power in the sphere of industrial and domestic establishment is assessed when we examine its jurisdiction of supply which terminates in Calcutta in the east and Patna in the north. The power supplied by Chandrapura has led to the mechanisation of coal mines and electrification of railways for transport of coal, iron-ore and steel goods.

The major industries located in Jamshedpur, Durgapur, Burnpur and Kulti area draw power from the DVC system. The coal mines of Jharia & Raniganj which produce about 80% of the coal output of the country, operate with power supplied by the DVC. The coal washeries at Kathara, Bhojudih and Dugda which produced washed coal for all steel plants in the public sector are dependent on DVC supply.²⁴

Sprawling along the industrial crescent of South-Eastern Bihar and South-West Bengal, the DVC complex has achieved the major objectives of power generation.

An analysis of the growth of power in Bihar shows that there is still room for water conservation for the utilization of water as a source of energy. The rivers of North Bihar have wide and extensive catchment basins which have not only to be studied from the point of reservoir but have also to be assessed as an area of high precipitation. Floods dominate the landscape in North Bihar. The recent flood in the Kosi is an index of what can happen to a trained Kosi. Training is still incomplete and further storage and dams in these rivers have still to be dotted more in its catchment areas in the Himalayan sector than in the plain Bihar. This is one of the multi-methods in which a new power map can be constructed in the rivers of North Bihar and its vast catchment area of the Himalayas.

The rivers of South Bihar having their source region on the rims of the northern slope of Chotanagpur are ready with

many pockets of water chambers which can be dotted to have plenty of small power sites in their sources and several others in the South Ganges plain before they feed the main artery, 'The Ganga'.

The breaks-in-slope at varying altitudes in Chotanagpur not only determine sites for waterfalls, gorges, etc. but are important natural sites for power restoration. The waterfalls like Dossan, Gautam-Dhara, Hundru, Hirni, Sadonighagh etc. can be utilized as congenial power sites provided knots of reservoirs are planned to regulate the flow of the waterfall to keep the turbine moving to electrify the forested tract to the best advantage of land and people. Every break in slope has ample room for supplying energy in its limited hinterland and every river with periodic swells has sites for dam construction to make at least a limited home of energy. There is little doubt that the safety valve of energy is a Thermal Power station which uses bad coal for good power.

In near future atomic power stations may be erected from raw materials supplied from the Dhalbhum area. To meet the power needs of the sixth and the subsequent plans, it is necessary to plan at least one super power station based on nuclear fuel of Bihar with 400 Kv transmission lines running north to south across the State. Considering all factors an expert has suggested Lohardaga as a site for such a super power station²⁵. A great interest has been stimulated on an international level to provide with nuclear powered agro-industrial centres. In keeping with this the operation of a large nuclear complex in the Ganga Plain has become the basis of a study by Dr. P. R. Stout of the University of California²⁶.

Efforts are being made to reduce the cost of production of power by new inventions and simple methods to provide cheap power to all activities of the State. This will further add advantage to the economic activities of the State.

A new 'Power Map' of the State has to be prepared with due weightage of power requirements, valuation of natural assets and accomplishment of man.

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JALDHAKA HYDEL POWER PROJECT AND ITS CONTRIBUTION
TO POWER PLANNING FOR INDUSTRIALISATION
IN NORTH BENGAL

Pijush Kanti Saha

Abstract

North Bengal, which has an area of about 6500 sq. kilometres (6.5% of the entire area of W. Bengal), appears to be a neglected part of W. Bengal from the standpoint of industrial development. Though the region possesses so many vast natural resources, proper utilisations are far from reality. The region occupies politically a strategic position with transport bottleneck.

Energy planning can play an important part in the total regional development. In a planned economy with predetermined magnitudes of development in all economic sectors, an assessment of energy requirement based on these goals should be more realistic and purposeful.

Though North Bengal does not have coal as energy contributor, industrial prospect of the region is not gloomy. North Bengal has abundance of white coal in the form of cheap hydel power. Based on hydro-electric survey the theoretical potential water power resources of the sites in North Bengal have been estimated at 1.3 million Kw (0.6 million Kw on the border with Bhutan and Sikkim) at 50 per cent load factor. Of these Jaldhaka basin has power potential of 1,50,500 Kw.

Jaldhaka hydro-electric project is the first major venture to utilise the power resources for the urgent need of electric power in North Bengal. The potentialities of Jaldhaka River have been known to many persons since as far back as 1918, when J. W. Mears undertook a reconnaissance survey of the potentialities. The whole project, in the reach of the river Bindu-khola and Naksal-khola is proposed to be executed in three stages. The power available at 50% load factor in the above stages are 36,000 Kw, 24,000 Kw and 24,000 Kw respectively, including 18,000 Kw & 12,000 Kw of secondary power in the first and second stages. Development of power potential in multiple stages in preference to a single stage development was favoured for reasons of morphology of the terrain, optimum utilisation of water resources, offering employment opportunities for a longer period and also to relieve heavy pressure on foreign exchange.

At present after the installation of the first stage only two turbines are working generating 18,000 Kw of power (9,000 Kw each). A third turbine is under installation, which will generate another 9000 Kw. There is provision for the installation of the fourth turbine with 9000 Kw power.

After the installation of the power house at Paren and working of the turbines, 2.6 Kw (Peak load) power was generated in the month of April 1968. Afterwards generations of power increased upto 5 Mw (approx.) in July 1968. During the month of September the generation was nearly about 7 Mw. But

after the devastating flood damage of October 1968, the power generation has fallen to less than 2 Mw at present.

Power from Jaldhaka is transmitted in two transmission lines—one transmission line supplying nearly 5,000 Kw to Siliguri (farther extended upto Darjeeling and Jalpaiguri) *via* Chalsa and Odlabari; the other transmission line supplying the rest 2000 Kw to Coochbehar *via* Banarhat.

Truly speaking generation of power at Jaldhaka power house is enough to meet the existing demand for power in North Bengal. But with the development of other industries, Jaldhaka alone cannot be adequate to meet the energy demand. Co-ordinated network of power transmission with other river valley projects will be necessitated.

N.C.A.E.R. surveyed development possibilities of both large scale and small scale industries in North Bengal for the period, ending 1971-72. These include cotton spinning mills, sugar industries, spun silk mills, chipboard plants, fibre-board plants, mechanical pulp plants, semi chemical pulp plants, integrated paper mills, formaldehyde and synthetic resins plants etc, agro, livestock, sericulture and forest based industries. Huge demand of power (at least 100 Mw) will be required by these plants.

North Bengal rivers with virgin power potential will not hesitate to supply these demands of energy. Even North Bengal in near

future may supply power to industrial South Bengal which is short of hydel power. With more hydel power from the north, coal rich industrial South Bengal will then be able to adopt a principle of conserving of coal.

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The North Bengal districts with an area of about 6,500 Sq. Kilometres (6.5 per cent of the entire areas of W. Bengal) appear to be the neglected part of W. Bengal from the stand point of industrial development. The serious lack of industrial development (both in the absolute and in the relative sense) has been reflected in the very low proportion of income earned by industries in the North Bengal districts :

Table 1

Composition of income generated, 1961

	Share of industry (per cent)	Agriculture (per cent)	Others (per cent)	Total (per cent)
N. Bengal	8.32	68.89	22.79	100
Rest of Bengal	27.89	33.76	38.35	100
Whole of India	19.50	47.00	33.50	100

(S.P.O.)

So it is evident that North Bengal is not only backward compared to the industrially developed Southern Bengal, it is substantially backward even compared to India as a whole. Thus relative industrial superiority enjoyed by West Bengal in India have not in any way been shared by the North Bengal districts. The region possesses so many vast natural resources which can be transformed into primary and secondary industrial products. But lack of proper planning, incentives and

capital investment by State and Central Governments have obstructed proper utilisation of the resources. The region on the other hand occupies politically a strategic position with transport bottleneck. Siliguri town, lying at the focal point, links up North Bengal with the Valley of the Brahmaputra in Assam, North Bihar, Sikkim and Bhutan.

Energy planning can play an important and dominant part in the total regional development. There is a close correlation between standard of living, per capita income and energy consumption per head. In a planned economy with predetermined magnitudes of development in all economic sectors, an assessment of energy requirement based on these goals should be more realistic and purposeful.

The principal factor which had retarded the development of industries in North Bengal is the chronic and acute shortage of power. It is to be noted with interest that though North Bengal districts accommodate nearly 15.97 per cent of the total population of West Bengal, these districts enjoy only 0.53 per cent of the total power consumed in W. Bengal. Now with the installation of Jaldhaka hydel project there is a rush for industrial power in North Bengal. On December 15, 1967 there were 91 new applicants for prospective bulk consumption of power with an ultimate demand of 18,653 Kw in Siliguri Division alone. Similarly in Malda Division there were 9 applicants for bulk power supply with an ultimate demand of 2,050 Kw of power. Though North Bengal districts do not have coal as energy contributor, industrial prospect of the region is not gloomy. Nevertheless, North Bengal has abundance of cheap hydro-electric power. Based on hydro-electric survey carried out by Central Water and Power Commission, the theoretical potential water power resources of the sites in North Bengal have been estimated at 1.3 million Kw (0.6 million Kw on the border with Bhutan and Sikkim) at 50 per cent load factor. The basin-wise distribution of these potentialities are as follows :

Table 2

Balasan-Mahananda basin	43,400 Kw
Tista (Great Rangit) basin	5,70,000 Kw
Torsa basin	4,00,000 Kw
Jaldhaka basin	1,50,000 Kw
Raidak basin	1,62,000 Kw
Total	13,25,400 Kw

These figures include only those sites, which are found to be more promising by preliminary hydro-electric potential survey. There are undoubtedly other sites which may have potentialities for generation of hydel power. These are : Sabagram (1,200 Kw), Phalut (400 Kw), Babing (4,400 Kw), Dandagaon (39,600 Kw), Kankibong (14,400 Kw), Barbatia (26,000 Kw), Miss (440 Kw), Nambo (600 Kw), Budhawari (7,200 Kw), Jhipi (700 Kw), Dilpa (6,400 Kw), Singbongdera (1,500 Kw), Bijanbari (4,000 Kw), Pullbazar (6,000 Kw), Barnesbeg (7,000 Kw), Manjhitar (1,900 Kw), Lopchu (1,100 Kw), Mangha (440 Kw), Badamtam (5,400 Kw), Dhamginbazar (720 Kw), Pubong (910 Kw), Dhaturia (1,100 Kw), Tong Song (1,150 Kw), Nagri (1,200 Kw), Avongrove (3,020 Kw), Namsu (1,720 Kw), Mirik (4,520 Kw), Ranchington (2,020 Kw), Manpu (5,600 Kw), Rambh (8,800 Kw), Labda (2,000 Kw), Jogijhora (2,200 Kw), Kashyem (14,200 Kw), Rhenok (1,400 Kw), Ladam (3,600 Kw), Pedong (1,600 Kw), Tumtang (1,850 Kw), Tar (1,400 Kw), Dilip Chand (1,100 Kw), Riasum (600 Kw), Sanjuk (1,470 Kw), Prengtam (1,500 Kw), Lungsel (1,640 Kw), Sivolbir (1,100 Kw), Pagrangbong (2,200 Kw), Paswong (1,500 Kw), Nimbong (2,200 Kw), Yangmakum (1,100 Kw), Parin (36,000 Kw), Samsing (2,665 Kw), Naksal (18,000 Kw), Sipchu (13,000 Kw), Cheloni (1,500 Kw), Taluk (10,000 Kw), Sukhani (1,000 Kw), Nagrakata (10,000 Kw), Salkapara (10,000 Kw), Tandu (17,300 Kw), in Tista (Great Rangit)-Jaldhaka-Balasan-Mahananda basin. Of these, Jaldhaka basin has power potential of 1,50,500 Kw.

Jaldhaka hydro-electric project is the first major attempt to utilise the power resources of North Bengal. From Bindukhola to Naksalkhola, Jaldhaka has a fairly good gradient about 1 in 40 on the average and a total fall of 305 metres favouring the generation of hydel power. The potentialities of Jaldhaka was known to many persons since as far back as 1918 when J. W. Mears undertook a reconnaissance survey of the potentialities, which he mentioned in his "Preliminary report on the water power resources of India". Attempts were made by many others in the following years and in later years topographical and hydrological surveys were conducted by Gruner and brothers to harness the potentialities of the river. Recent investigations done by West Bengal State electricity Board was submitted to the Planning Commission for inclusion of the scheme in the second plan programme. The whole project, the reach of the river Bindu-khola and Naksal-khola is proposed to be executed in three stages. The first stage will utilise a drop of 177 metres in between Bindu-khola and Biru-khola. Second stage will be commissioned to utilise a fall of 91 metres in between Biru-khola and Naksal-khola, while the third stage envisages to utilise a drop of about 396 metres on the Ni-chu further upstream of Bindu-khola confluence. The power available at 50 per cent load factor in the above stages are 36,000 Kw, 24,000 Kw and 24,000 Kw respectively including 18,000 Kw, 12,000 Kw of secondary power in the first and second stages. The lower reaches of Jaldhaka beyond Naksal-khola also promise a good potential to the extent of 77,000 Kw. Development of power in multiple stages in preference to a single stage development was favoured for reasons of morphology of the terrain, optimum utilisation of water resources, offering employment opportunities for a longer period and also to relieve pressure on foreign exchange.

At present after the installation of the first stage only two turbines are working in generating 18,000 Kw of power (9,000

Kw each). Third turbine is under installation which will generate another 9,000 Kw. There is provision for the installation of the fourth turbine with 9,000 Kw capacity.

After the installation of power house at Paren (Jaldhaka H. P. station) and working of turbines 2.7 Mw (peak load) power was generated first in the month of April, 1967. Afterwards generation of power increased upto 5 Mw in the month of May, 1968. During the month of September maximum peak load generation was nearly about 7 Mw. But after the devastating flood damage of October, 1968 the power generation had fallen to less than 2 Mw. The picture will be revealed by the following data :

Table 3

Peak load (Max) generation of Power at Paren in Mw

1967—April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
2.7	2.6	2.8	3.0	3.2	3.1	3.5	3.5	3.7
1968—Jan.	Eeb.	March	April	May	June	July	August	Sept.
4.0	4.5	4.4	4.8	5.0	4.9	6.4	6.6	6.8
Jaldhaka Power House								

Power from Jaldhaka is transmitted in two transmission lines. One transmission line supplying nearly 5,000 Kw to Siliguri (further extended upto Darjeeling and Jalpaiguri via Chalsa and Odalbari ; The other transmission line supplying 2,000 Kw to Coochbehar via Banarhat. Jaldhaka project envisages a network of 66 Kv, 33 Kv and 11 Kv transmission

lines to cater electricity in districts of Jalpaiguri, Coochbehar and Darjeeling.

Truly speaking generation of power at Jaldhaka along with other small unit diesel stations (i.e. at Malda, Siliguri etc) and mini hydel stations (i.e. Kurseong, Larin Khola etc) are enough for existing industrial power need of North Bengal. According to a spokesman of West Bengal State Electricity Board, at present power requirements are 2000 Kw for Siliguri urban area and 4,000 Kw for the whole of Darjeeling District. But with the development of major industries Jaldhaka (as single major hydel power generator in North Bengal) cannot alone be able to supply energy demand for North Bengal. Hydro-electric potentialities in other major river basins must be exploited and a co-ordinated network of power transmission will be necessiated.

The N.C.A.E.R. surveyed the development possibilities of both large scale and small scale industries for the period ending 1971-72. The major industrial set up may be noted from the following table.

Table 4

Development possibilities of large scale industries in N. Bengal

A

Agro, livestock and sericulture based industries

Type	No. of unit	Location	Installed capacity
1. Cotton spinning	3	Jalpaiguri Raiganj Malda	(1) 29,000 Spindles and (1) 5,500 looms (1)

Type	No. of units	Location	Installed capacity
2. Sugar industry	4	Jalpaiguri (1) Cooch Behar (1) W. Dinajpur (1) Malda (1)	610 tonnes of cane per day
3. Spun silk mills	1	Malda	27,215 Kilograms of (1) spun silk per year.

B

Forest based industries

Type	No. of units	Location	Installed capacity
1. Chipboard plant	1	Siliguri/Jalpaiguri Region	5,486 tonnes per year
2. Fibre board plant	1	Siliguri/Jalpaiguri Region	4,572 tonnes per year
3. Mechanical Pulp-plant	1	Siliguri/Jalpaiguri region	2,032 tonnes per year
4. Semi-chemical pulp-plant	1	Siliguri/Jalpaiguri region	30,048 tonnes per year
5. Integrated Paper mill	1	Siliguri/Jalpaiguri region	30,048 tonnes per year
6. Formal dehydel Resins plant	1	Siliguri/Jalpaiguri region	1,016 tonnes of liquid resins (65 per cent dry solid content) per annum.

N.C.A.E. R.

There are also possibilities for developing small scale cottage industries. But the establishment of different forest based industries may be faced with serious question of the regular supply of forest resources.

Table 5

*Annual increment and exploration of timber
by type in Nn. circle*

Type of timber (in thousand cubic feet)

Particulars	Constructional	Furniture	Ply wood	Teak	Match wood	Pulp wood	Box wood	Total
Gross annual increment	105	24	46	17	24	45	131	392
Average annual cut (1961-64)	71	5	9	—	3	—	8	96
Percentage of cut to annual increment	68	21	19	—	13	—	6	25

Planning & Statistical Cells,
Directorate of forests.

Thus even under the present context a few forest based modern industries may develop in nears future with prospective harvesting of different types of timber. With the exploitation of artificially regenerated area the development will be accelerated. However, development of forest based industries in North Bengal will require tremendous supply of power. Along with other industries the total requirement of power will not be less than 100 Mw. The Siliguri area will require an estimated demand of 50 Mw in the fourth plan period. Truly speaking, the potential demand of power in North Bengal for future years has never been estimated. However, it may be stated that with an estimated average demand of 150 Kw per tea factory, nearly three hundred tea estates in Dooars, Terai and Hills will consume approximately 45 Mw

of power as a single industry. Similarly high industrial demand for power has been estimated from projection on the basis of estimated per worker requirement of power in Siliguri Urban Zone only.

Table 6

Projected power demand for Siliguri Urban Zone

Industry group	Standard H.P.	Demand in 1971 in Kw	Demand in 1976 in Kw
Food etc	1.2	2517	4169
Textile	0.45	328	498
Wood & Wood based industry	1.5	2481	4548
Printing	0.5	92	158
Chemical	0.5	228	478
Transport	0.4	839	1264
Engineering	1.1	1003	2274
Others	0.3	328	162
	Total	7816	13551

From our earlier study of hydro-electric potentialities of North Bengal Rivers, it may be stated that North Bengal rivers with virgin power potential will not fail to supply the total demand of energy. Jaldhaka Power house at Paren as the pioneer one will contribute efficiently to the future requirement of power with subsequent development of other stages in the Jaldhaka. Even North Bengal in near future may supply power to industrial South Bengal which is short of hydel power. With more hydel power from the north, coal-rich industrial South Bengal will then be able to adopt a principal of conservancy of coal.

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Post Script

Recurrent flood damage at Jaldhaka hydel power station has resulted in power famine in N. Bengal. It has been revealed in the earlier study that power shortage was a major problem even before the installation of Jaldhaka hydel power project and hence resistant to industrial promotion. Now the

entire North Bengal is in the tight grip of power famine and the power based industries like engineering have been hard hit. Even the tea industry would suffer to a great extent. This set back in the fast developing industries in the region is likely to erode the newly acquired growth momentum.

To conserve the industrial growth momentum in the region comprehensive power planning would be essential in forming a well built central grid power system. Installation of thermal power station along with transfer of power from the surplus states Bihar & Assam would be necessiated immediately to conserve the power in a central core.

ELECTRIC-POWER DEVELOPMENT IN UTTAR PRADESH

Indra Pal

Abstract

Since the first quarter of the 20th century, the interest and enterprise of the State Government for generation and supply of electricity was primarily for lift irrigation from tube-wells in areas where irrigation by canals was not possible. So a chain of small hydro-electric stations was constructed on the Upper Ganga Canal utilising falls between 4.5 and 5.7 metres, and supplemented by thermal stations suitably located in the region. In the present paper the Harduaganj complex has been studied and similar areas within Uttar Pradesh have been indicated.



As India has a large population with both agricultural and industrial backwardness, so is Uttar Pradesh, the State with the largest population, but rather backward both agriculturally and industrially

Since Independence the Central aid has been allotted to the states which had their programmes for industrial developments, and Uttar Pradesh has ever suffered on the ground that it has been merely an agricultural State. The plea that the Central aid be distributed on the basis of population has never been accepted. So it has started exploring its potentialities for industrial development. The author produced a successful thesis on Industrial Planning in Uttar Pradesh and explored the scope of industrial development which may provide employment to about half of its population.

The base of all industrial development being the power, its growth is directly related to the amount of electricity that a region can generate. The paper proposes to discuss the

hydro-electric potentials, its development, distribution and load in the State. After the implementation of the proposed plans if Uttar Pradesh with its poor and deficient mineral resources cannot be made the Ukraine or the Ruhr of India, it can with its latent power be turned into the Tennessey Valley of India and thus poverty and squalor can be made things of the past.

Since the first quarter of the 20th century, the interest and enterprise of the State government for generation and supply of electricity was primarily for lift irrigation from tube-wells in areas where irrigation by canals was not possible. So a chain of small hydro-electric stations was constructed on the Upper Ganga Canal utilising falls between 4.5 and 5.7 metres. Since these suffered from vagaries of nature resulting in lean discharges during certain parts of the year these were supplemented by thermal stations suitably located in the region.

Apart from this, power development in the State was predominantly by several relatively small isolated thermal stations serving the principal cities.

In 1920 the State was third on the power map of India. The total installed capacity in 1951 was 160,000 kilowatt, in 1955 it was 170,000 kilowatt and in 1960 it rose to 378,000 kilowatt including hydel, thermal and diesel installations. It is contemplated to increase it by 1,000,000 kilowatt, nearly two-third of what the entire country had at that time or London had it in 1938 only in its six generating plants.

Careful investigation has shown that the construction of a peak load steam power station at Chandausi for energizing the tube wells in the Moradabad and Badaun areas is cheaper than the alternative of constructing two or possibly three additional hydro-electric stations on the canals some 240 kilometres apart. These thermal stations when brought on the grid would be complementary rather than competitive. For these advantages thermal power generation in the State is about 1,20,000 Kilowatt far in excess of hydel power, nearly six times the normal output of hydel plants.

Although there is no significant coal in Uttar Pradesh it predominates in thermal power. Contrarily the natural forces have produced a topography of folded and fractured rock structures, both in the north and south of the State, which although hampers settlements and communication, provide geographic features for the generation of power from falling streams. But the inundation characteristic of streams flow is the chief impediment to the development of water-power resources of the State. Feast or famine describes any of the steep rivulets of the hills.*

The map No. 1 shows the distribution of sites surveyed for power stations in the State, their potentials, firm and seasonal. The other map shows the power stations and transmission lines. On the basis of these maps the service of electricity may be divided into four major power systems namely, the Ganga Canal Hydel Grid, the Sarda Canal Hydel Grid, the Rihand Obra Hydel Grid and the Kanpur Mata Tila Power System.

The Imbalance in Regional Development

The Western Zone of Uttar Pradesh served by the Ganga Grid is the most developed of all the regions of the State. The Central Zone served by the Sarda Grid and the Eastern Zone served by the Rihand Grid are moderately developed. The Bundelkhand Zone is poorly served.

At the time when India was threatened by Japanese invasion, the Bhatpara power station (West Bengal), with a capacity of 20,000 kilowatt situated on the Hoogli was accommodated on the Ganga grid system at Harduaganj (Kasimpur, Aligarh District) and was arranged to supply power to the ordnance works and shadow factories. Now it has developed into a power-complex.

* Flow in the Sarda Canal varies from 9,500 to 4,000 cusecs. This results in the variation of power output from 38,000 Kw to 20,000 Kw which in very dry years may drop even to 16,000 Kw.

The thermal power complex at Harduaganj occupies an important position in the Uttar Pradesh power system in as much as it can be called the power nerve centre of western Uttar Pradesh. The gradual building up of this station in post war years from 20 Mw to 110 Mw during the Third Plan and 210 Mw in 1968 is indicative of the fact that power station is playing a very useful role in ushering the era of plenty and prosperity in this region both in agricultural and industrial sectors.

It was in this background that a modest beginning was made by constructing small capacity thermal stations at Harduaganj on account of the several inherent advantages which this location possessed or still possesses over other sites. The augmentation of the generating capacity at Harduaganj in stages was considered essential in the context of meeting the agro-industrial load requirements of this region which sprang up at a much faster rate subsequently.

In western Uttar Pradesh the pressure of setting up large industrial complexes centred round Meerut, Modinagar, Muradnagar, Ghaziabad, Aligarh, Hathras, Mathura, Agra and Moradabad. etc., This region, however, experienced acute shortage of power during the Third Plan. There was ban on free sanction of load for the last several years. In spite of these restrictions on development of load, rostering had to be resorted to every year during peak season. This situation called for setting up immediately of a power station in the western part of the State.

The centre of load demand is located in the central part of the area bounded by the aforesaid districts. It was, therefore, necessary to locate a thermal station of adequate capacity in the load centre itself so as to obtain advantages inherent in such a location. The advantages accruing from such a location are less transmission reinforcements, elimination of gap between generation and utilisation and early gains from the capital invested. Harduaganj, therefore, afforded a suitable site for location of such a thermal station as it

commands about 120 kilometres as shown in the map of western UP.

Situated as it is in the centre of Uttar Pradesh power and in close proximity of major load centres, the Harduaganj power station contributes to a large extent to these inter-connected operation. In this power system, the two most distant electrical power complexes are Rihand-Obra complex in the south-east and Yamuna complex in the north-west and if there were no intermediate power complex, the angular difference between these two complexes shall have been fairly large for given power transfers and inter-connecting facilities. However, due to the establishment of a big power complex at Harduaganj, the long route of power flows has been subdivided into two parts viz. Obra-Harduaganj and Harduaganj-Yamuna. This has resulted in a considerable reduction in the net angular difference of voltage vector of most distant machines and the consequent improvement in the transient stability of the system to a large extent.

There is a large concentration of loads near Harduaganj due to proximity of such industrial centres as Ghaziabad, Meerut and Modinagar, Aligarh, Agra etc. and correspondingly the reactive power requirements of this area are also quite large. But for the location of Harduaganj power station, this reactive power would have to be supplied from distant generation sources, resulting in heavy line losses and adverse stability effects.

Coal has to travel all the way from Bihar coal fields to Harduaganj to feed this power station, a distance of more than 1,000 Kilometres. Relative study of siting a thermal generating station in the vicinity of coal fields and transmission of power by high tension lines against transporting coal to a distant thermal power station situated afar for certain other reasons shows results in favour of the former. This is quite a significant point affecting the economy of thermal power generation and transmission. Still situation of Harduaganj power station is

peculiar in its own way and the many other advantages associated with this peculiarity render this important aspect rather insignificant.

Harduaganj power station ensures reliable supply to loads of various categories. It is connected on 220 Kv. with both Kanpur-Rihand system and Muradnagar by double circuit lines. This is also proposed to be connected very shortly with Moradabad on 220 Kv. single circuit line. Besides this, a number of 132 Kv and 66 Kv radial feeders emanate from this station. Harduaganj also serves as an important link between the generation complexes in the northern and southern parts of the State for exchange of power. Thus Harduaganj power station ranks high in overall generation picture of the State and fits in well in guaranteeing uninterrupted supply to a large number of industrial consumers of various categories spread over this western region of the State.

A perennial canal passes by Harduaganj and this helps a great deal in cutting down the cost of supplying water facility for the power station. No cooling towers were required for extensions in Stage Nos. I, II and III. This meant a substantial saving besides having operational advantages from such an arrangement. All the power generated from Harduaganj is consumed in close vicinity around it and this means reduced line losses and utilisation of maximum energy for productive purposes.

The advantages of power grid system are very well known. With the same installed capacity the grid helps in the greater utilisation of power potentials of different regions to be shared mutually. With the same point in view the four grids have been inter-connected at 132 Kv or 220 Kv and 38 power stations now feed into this integrated power system.

The Uttar Pradesh grid has also been connected with the DVC system in the east and with Delhi Power System in the west, and it is proposed to connect it with Bhakra system in the near future.

Suggestions

From the data given in the Appendix it is clear that just as a power complex has developed in the western zone, a power complex is developing in the Mirzapur area and another will develop in the north zone with the completion of the Yamuna Valley and the Ram Ganga Projects. With an installed capacity of 1187 Megawatts at Harduaganj, the maximum under any state electricity board in the country at present, they have planned to increase the capacity almost double this figure by the end of 1974. But the projected rise of demand, particularly on account of the fast developing agro-industrial complex indicates that they would still be short of power. In order to bridge the gap it would be essential to install a large Hydro-electric Peaking Power station at Pancheshwan or at Tehri and also an atomic power station which is dropped from consideration by the Atomic Energy Commission. It was likely to be sited at Narora, the headworks of the Lower Ganga Canal. For all these developments this State is the first in the country to commence planning of 400 Kv transmission lines.

All this means that the north-eastern and south-western parts of the state would remain deficient in power, the former is in the famine zone and the latter in the under-developed region of the State. The central districts of Mainpuri, Etah and Farrukhabad are already nick-named as criminal districts. Therefore, either additional thermal plants be established for these districts or an atomic energy plant be considered in this area. For the south-west or Bundelkhand area the Betwa river be developed to the maximum capacity.

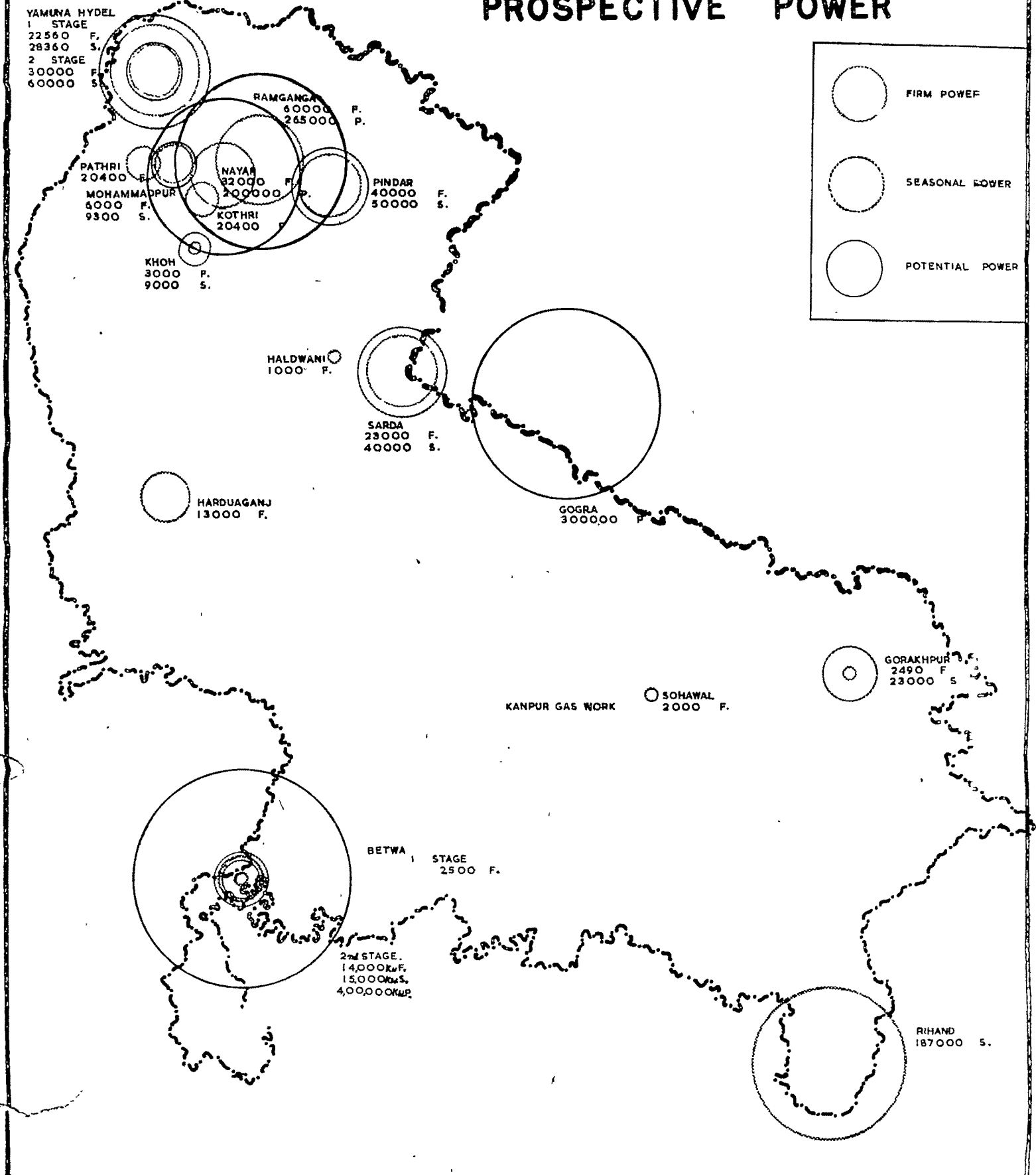
A large number of small hydel power stations may be installed in the northern Himalayan region (Kumaon) with a view to establish small industrial estates in the under-developed parts of the State and to strengthen our northern frontiers.

For the potentialities of lift irrigation electricity is a hidden wealth which could be fully exploited. The number of tube-wells in the State can safely be doubled. The tail ends of the

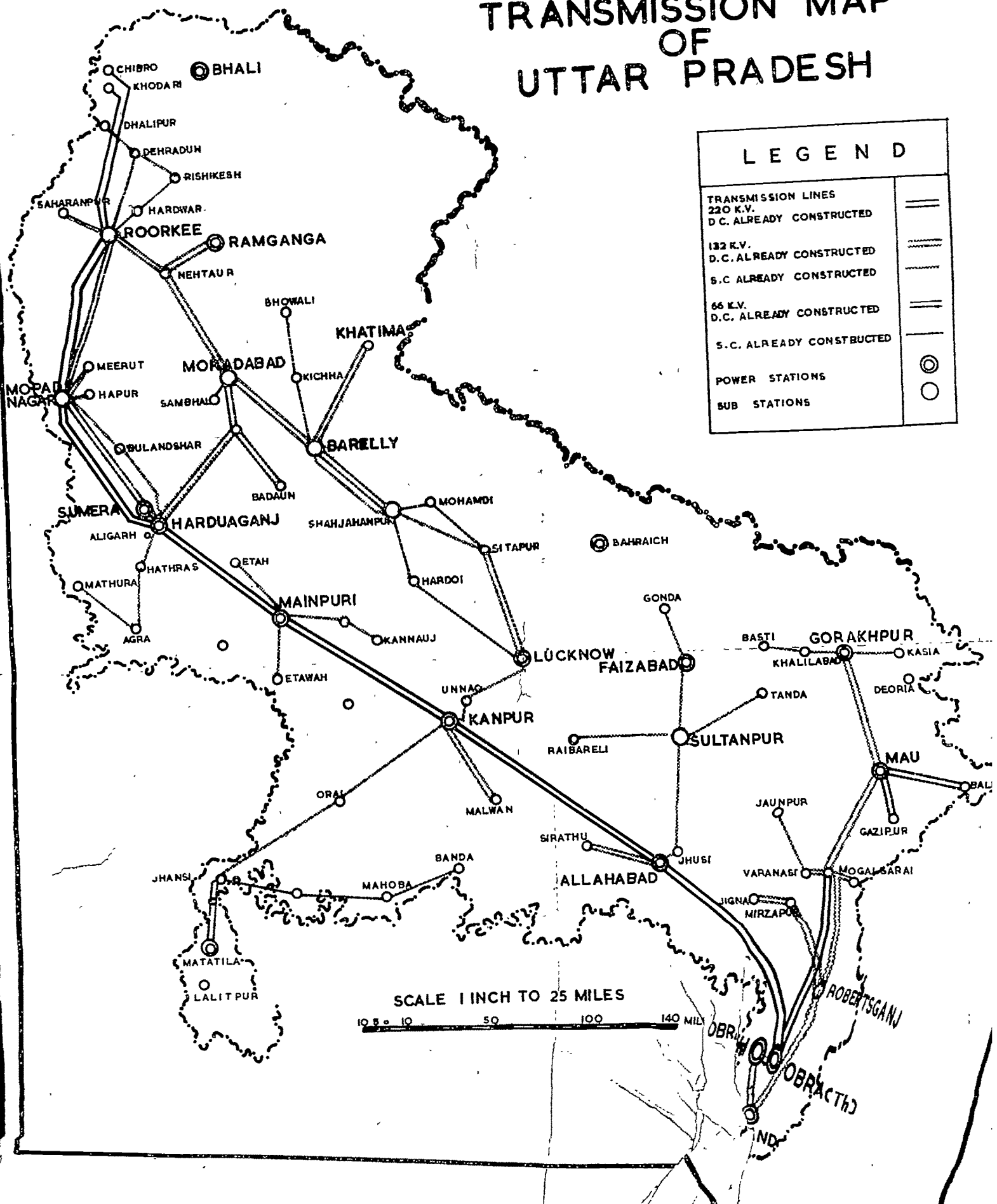
Ganga canals in the central districts are three to five metres deep and they suffer from irrigation difficulties. The water from these canals can be lifted for the agricultural prosperity.

The state power-grid should be extended to the Hirakund and Chambal valley projects. There are many steam stations and oil engine stand-by-plants at various local centres in the State and run by individuals for personal gain. All these power stations can be interlinked if the government takes over charge of these power stations. We should not only be satisfied with establishing an all India power grid but also coordinate with schemes like the Karuali river in which Nepal is also interested. Thus an international grid can be contemplated for the greatest good of the greatest number.

PROSPECTIVE POWER



TRANSMISSION MAP OF UTTAR PRADESH



WATER RESOURCE—ITS TREND AND PATTERN IN THE
POWER DEVELOPMENT IN INDIA

Niranjan De

Abstract

Water as a material of multiple use provides an easy break—through in the vicious cycle of low per capita production and utilization of a few resources in which the developing countries are swirling. The utilization of waters in India before 1950 was meagre and water power production was small and limited to areas away from coal, the then competitive source of energy. A sharp increase in the utilization of water with the inception of Five Year Plans, offered a facility perhaps unique in the world for the development of water power and the resulting mushroom growth of hydro-electric stations changed the pattern of power supply manifesting a shift from the specialized hydro or thermo-electricity to hydro-thermo-mix-up power zones.

In the resource pyramid, the resources of power though occupying the pinnacle, developed at a rate slower than that of regional resource in general. This is due to the failure not only of resources of power to lure factors of production, but of the developing region to offer facility for generation of electricity which is capital intensive.

With the attainment of the "take-off" stage for industrialization, there ensues electricity production utilizing the regional resources. Its rate of growth though lagging initially behind, surpasses ultimately that of general industrial activity. It acquires thereby a "self generating" force, the operation of which leads to chain reaction like that of a nuclear reactor. In the run of the cycle, hydro-electricity runs to, then, runs after demand and then runs together with the thermal electricity to fabricate a pattern of power mix-up.

Developing countries are characterised not only by their low per capita production, but by the utilization of a few materials of Nature. In many cases, a cause and effect relationship between them can be visualized and these two run in a vicious cycle. Water as a material of multiple use, provides the easiest break-through. It not only increases the agricultural productivity per man and per acre, but helps to restore the productive capacity of land, which has so long been wasted away by the unscientific cultivation. Water power in the form of horse power furnishes extra productive capacity for man and facilitates for him, the utilization of other materials, through the magic of electric power in the form of light, heat and magnetic energy. Further, water as a resource has a negative quality, if not properly used; it could be as has so often been the case in India—a resistance; it destroys life and property by recurrent floods.

In undeveloped countries, where skill and capital are scarce, the abundance of material is perhaps the most important factors in the utilization of resources¹. Water among all

1. Dr. Niranjana—The Development of Iron & Steel Industry in India a study in Industrial Geography—A thesis submitted at the University of London (unpublished) 1953, P. 22.

materials offers the best facilities for utilisation for its easy availability its self fuelling property and its versatile utility in the field of processing. In other wards, water is itself the material to be used, and it supplies the means of material use. Water therefore has acted as a spark in the economic development of many areas. Outstanding example may be cited from the countries situated in the coniferous forest zones.

In India the earliest development of water power, though started before the dawn of the present century in Darjeeling, the progress upto the beginning of our Five-Year-Plans were very slow. The development has been very rapid since 1951—obvious from the following table (Table—1) :

Table 1

Development of Water-Power Resources in India

Year	Developed water-power (in Kw)	Percentage of potential Resource utilised for	
		Irrigation	Power Generation
1950-51	560,000	17	1·3
1955-56	940,000	22	2·3
1960-61	1,980,000	27	4·7
1965-66	5,100,000	36	12·4

Source : 2nd & 3rd Five-year-plans—Government of India, Planning Commission. The percentage of utilized water power has been calculated on the basis of the estimated potential water power of 41,000,000 Kw and that of irrigation from the potential source of 480,000,000 acre feet.

In summary it may be said that we developed in the First-Five-Year Plan as much as we did in the past 50 years. In the next plan, it was doubled and in the next, more than that again. As a result the percentage of water power developed in India jumped from a mere 1 to a respectable figure of more than 12. In the same period, the percentage

of water potential utilized for irrigation rose from 17 to 36. I am not indulging an excursion into the tricky lands of Statistics, the important fact however stand out—the industrial development of India is in full swing in which, curiously enough the recent spurt in the use of water is the result not of the creation of resources but of the prevention of the destruction of resources—that is to control flood.

Table 2

Development of Electricity in India

Year	Total electricity (capacity in Kw)	Thermo-Electricity (capacity in Kw)	Percentage of hydro-electricity to total
1950-51	2,300,000	1,740,000	24
1955-56	3,420,000	2,480,000	28
1960-61	5,700,000	3,770,000	34
1965-66	12,690,000	7,590,000	40

Source : 2nd & 3rd Five-year-plans—Government of India, Planning Commission.

In electricity development (Table-II) we find the same trend—a five fold increase in three five year plans. But the growth of hydro-electricity soared at a rate double of that. As a result, the contribution of hydro-electricity increased from 24% to 40%. Before 1951 the electricity from coal and petroleum supplied two third of our total electricity production, a production pattern conforming to those of highly developed countries of the world, where in recent years only, thermo-electricity is being developed at rate faster than that of hydro-electricity, which is reaching the limit of potential capacity.

This shift of emphasis in the source of electricity production is the effect of the integrated use in recent years of water

resources, which has acted as a cause of the changing pattern of electricity development. Since the early eighties of the 19th Century when Edison realised that electric current could be generated by special plants and delivered at home like water, morning milk or morning newspaper, water was considered just another source of electricity in addition to coal and petroleum. So it could be developed, if it could compete with thermal electricity. Fortunately India is blessed with large potentials of water power in the Western Ghats and in the Himalayas. These areas are favourably situated being far away from coal—the main source of electricity. Unfortunately for India, the huge capital required for building storage reservoirs up in the hills and the long transmission lines to the urban centres in the plains, were not forthcoming. So the conditions favourable for the development of water power could only be found in few places. However with the turn of the century, water power developed at Sivasamudram, as it offered wonderful facilities of a perennial natural waterfall, and a large nearby market in Kolar gold field. The power resources of Western Ghats, in close proximity to Bombay were also developed under similar favourable conditions, though requiring large capital investment for storage dams.

Just before the first world war, we therefore find, a region of hydro-electricity in the process of development around Mysore-Bombay, and a region of thermo-electricity comprising the rest of the country. Further development was delayed for the lack of capital necessary to regulate the violent fluctuations in the flow of Indian rivers. The phenomenal growth of irrigation on a national scale, by rendering a condition of veritable nature—made regulation of flow helped the extension and intensification of the regional pattern of electricity. Incidentally this is the first step towards the integrated use of water as a resource. The storage irrigation of south India provided such a facility that only the setting up of turbines and transmission lines were required to inaugurate a flow of power outlasting that of many large coal fields. No doubt there

were difficulties of market, but power could be developed in stages. The magnificent perennial canal system of the Uttar Pradesh and the Punjab, which run in a series of falls offered equally favourable facilities for power generation. Just before the Second World War we find three electric zones—the zone of thermal electricity, extending from the North East borders through the Coal Belts, running up to the borders of Rajasthan separating the two hydro-electric zones the larger one in the South West in the Deccan and the smaller one in the North West in the Uttar Pradesh—Punjab Region.

The inception of the plan for industrialization led to the initiation of the intensive and integrated development of water resources. The countryside became honeycombed with innumerable reservoirs, either to control flood or to store irrigation water or for both. Those reservoirs provided a facility for the development of water power, perhaps unique in the world. Consumption—"The sole end and purpose of production" increased much in response to industrialization and stimulated power production. India as a result experienced a boom in the growth of hydro-electric station both in the horizontal and vertical direction. This however, instead of sharpening the specialized pattern of electricity zones, has tended to develop a regional pattern of hydro-thermo-power mix-up in many areas. The development of two multipurpose projects—The Damodar and the Mahanadi, brought hydro-electricity into the very heart of thermo-electricity—the coal belt of India. Hydro-power, which was so long developing in distant areas and slowly gathering momentum, increased its tempo and suddenly invaded the capital of "King Coal". It is not that coal has been exhausted, not that the price of coal soared to an uneconomic height, but by the urgent economic feasibility of developing water power consequent to the integrated utilisation of water resources. Coal is an wasting asset, but if not utilised, it remains in fund, but water-power though popularly known as lasting asset becomes an wasting asset, if not utilised

at that very time and very place. Therefore water power commands a priority in the regional scheme of resource utilisation.

This changed pattern of regional electricity development has brought a diversification in the pattern of power site development which was so long confined to power sites situated mainly in the plains and in the low plateaus. Now with the growth in demand for power and the facility in the availability of capital, water-power sites are being developed higher and higher, up in the hills and mountains of the Western Ghats and the Himalayas. Civilisation, so long marching along the courses of the rivers downwards has reversed its direction, as if, for the time being to advance up the mountains. In the process of resource development many marginal resources become economic, bringing into play a train of geographical sequences converting those sources of marginal resource into central sources creating in its orbit of operation other marginal resources round those sources.²

With the intensive utilisation of water-resources, the pattern of development of individual power sites also altered. Owing to limited local demand and the prohibitive cost of transmitting electricity to long distances many water-power sites developed a portion of its ultimate potential capacity. Now with the growth in demand consequent to the coming of many new industries adjacent to power sides and the economic feasibility of transmitting power to long distances through high-voltage transmission lines, water-power sites are being developed to the limit or potential capacity. The Jog-falls, just to give an example which generated 60,000 Kw of power in its inception in 1947³ has an ultimate capacity of nearly a million Kw—a large part of which has now been developed.

In contrast to the introduction of hydro-power in the coal-belt, thermo-power like the tidal flow after its ebb, has again

2. De, Niranjana—Op. cit—p. 109-112.

3. De, Niranjana—Op. cit—p. 157.

staged a spectacular come back in the Bombay industrial area, half a century later. As the consumption of coal for 1 Mw electricity registered a sharp decline from 7 lb to less than 1 lb⁴ during this period coal, acquiring a new mobility, underwent a geographical revolution. The industries so long were moving to coal but now coal is moving out to industries. The phenomenal growth of industries in recent years in Bombay region has created such a spurt in the demand of power as to outrun the supply. Water-power is everlasting, but not infinite*. As our agriculture needs irrigation though rainfall is heavy and regular, so the developing industries in Bombay region requires supplementary supply of electric power.

These examples will serve to illustrate the tendency of a region to develop a mix-up power pattern of hydro-thermo-electricity, which were so long competitive, but now have become complimentary in the regional power pattern. It is a sort of power revolution. In the industrial society we are living both the thermo and hydro-electricity have their respective sphere of utility. Coal is exhaustible but adequate whereas hydro-electricity though inexhaustible, is inadequate and their coordination provides the ideal solution in such situation. The technical efficiency of thermo-electricity in the power production for firm load and that of hydro-electricity for peak load have been adjusted in supplying the daily demand of power which exhibits the pattern of a diurnal tidal ebb and flow. Over and above this daily periodicity there are annual and other periodicities of longer durations in response to business cycle. Had the rainfall regime coincided with the demand cycle it would have been ideal but that is nowhere so. The irregular flow of water, it is no doubt possible, to regulate, to meet the periodic fluctuations in demand, but the cost would rise to an uneconomic height and as such what is done is to

4. Woytinsky & Woytinsky—World population and production-Trends & Outlook, Twentieth Century Fund, New York 1953, p. 946,

★ Thanks to my physicist friend Prof. S. K. Sen, M.Sc., Ph.D., of Chandernagore College for suggesting this appropriate term:

produce power as the flow allows it. The balance in the surplus and deficit in the regional supply, is achieved to a great extent by the transmission to and from other areas as is done in Italy where the summer maxima of hydro-power from the Alps is linked with the winter maxima of the Italian Peninsula. As however such favourable conditions are found in few areas, the only recourse left is to generate thermo-electricity and this is why in no country we find hydro-electricity is the only form of electricity produced. Everywhere a pattern of power mix-up in the ultimate stage is the irritable process of growth and development.

This weaving of a pattern of power mix-up, a full century after the inception of industrialisation in India⁵, represents the usual time lag in the utilisation of the resources of power. In the resource pyramid we can visualize the resources of power forming the pinnacle on the base of the regional resource, the development of which brings in its sequence, the edifice of power, in view of the fact that power which multiplies the productive capacity and accelerate the processing activity of man many times will be chasing the regional economic development. In a developing country other factors of production—labour, capital and organisation are in short supply even to satisfy the direct demand and any diversion of a part of them to meet the derived demand of power will hamper instead of helping the normal trend of development. Again the cost of power with the exception of a few power intensive industries like electro-chemical and electro-metallurgical industries, rarely exceeds 10%⁶ in the total cost of production and in textile industry it comes down to 4%⁷. With the resources of power constituting only a small part of the

5. De Niranjana—op. at.—p. 47.

6. National Resource Planning Board—Industrial Location and National Resource—Washington, 1943, p. 161.

7. National Resource Planning Board—Op.cit. pp. 157-161.

total resource complex of a region, its importance may be likened to that of gypsum in the cement industry, the development of which is not influenced materially by the facility or scarcity of regional supply of gypsum. Further, the resources of power do not produce a material like gold, the lure of which favour the deployment of the forces of utilisation. The development of electric power is also handicapped by the perishable nature of the finished products which should be consumed in a market close-by. The production of electricity being capital intensive⁸, is economic only in large units. A poor country lacks capital to produce it and markets to consume it. Although in developing country in the early stage of industrialisation, both capital and market start growing, but they are too small and too diffused to facilitate the economic utilisation of regional resources⁹ for electricity. Under such conditions where the demand does not exceed 250 kilowatt¹⁰ the production of thermal electricity is economical utilising only diesel oil even from extra regional sources. With the development, a stage is reached when the markets though retains its scattered pattern, increase in size to offer facilities for the generation of electricity from regional resources. As the transmission of power is economically confined to an average radius of 25 miles¹¹, to avoid loss running upto 14%¹² in low voltage system, the markets are served by independent power stations. Even at this stage, as has been the case with South India a few decades ago, it is economical to utilize coal from extra-regional sources to generate electricity inspite of plentiful potentials of hydro-electricity.

8. Zimmermann, E.W.—World Resources and industries, Harper & Kow, N. Y. 1948, p. 605.

9. De, Niranjan—Op.cit p. 59.

10. Manners, Gerald—The Geography of Energy, Hutchison, London, 1965, p. 113.

11. Mauzau O. T.—International Resource and National policy, Washington, 1947; p. 397.

12. Manchester Joint Research Council-Economic Aspect of Fuel and Power in British Industry, 1958, p. 176.

As, however, the developing economy attains the "take off" stage, as propounded by Prof. Rostaw, there ensures an acceleration in capital formation ensuring a flow of investment in water power development. The increasing size of the existing market facilitating the consumption in bulk, and the rise of new markets favouring interconnections between the generating stations, widen the horizon of electrification. As a result the condition becomes favourable for the large scale production and consumption of hydro-electricity utilizing the regional resources of water the trend of which is intensified in the absence of coal in the region.

This stage stands as a milestone in the growth of electricity which in its "lag phase" trailing so long behind the general resource utilisation has entered the "log phase"* (to borrow a term from pathology) manifesting a tendency to outpace its rival. In the energy production which is capital intensive, the larger the scale of operation, the cheaper is the cost per unit. There is as such a natural tendency for the power centres to produce in excess of the demand in a way not to impair the economy of operation. So there is, in general, some extra-power left to offer at inviting rates to the incoming industries. Electricity it is true, is not economical in many instances, but its versatile quality creating it economic in convenience, control and conversion copiously compensate its cost and lure its consumption. Therefore, an electric generating centre extends its horizon radially exerting its centrifugal force and as if to counteract it industries conglomerate centripetally. The operation of this process leads to a chain reaction like that of a nuclear reactor—the larger the production, the cheaper the cost, the longer the supply, the greater is the utilisation of resources. The electricity generating centre in the very process of growth and development acquires a self generating force which extending in ever widening circle creates a Geographic Base too large for the regional resources of power

* This term is used to describe the stage in the growth cycle when bacteria multiply in logarithmic progression.

to supply adequately to a stage where the diseconomies of centralisation over-weigh the economies of decentralisation.¹³ But a hydro-electric station is self limiting, it can develop up to its potential capacity which is attained quickly as the incremental cost of hydro-power is lower than the corresponding cost of thermopower.¹⁴ The large surplus of power resulting from such rapid increase in the supply facilitates a sudden expansion in the horizon of transmission. So the centrifugal force is strong in the early stage. As the cost of distribution forms 60%¹⁵ of the total cost of electric power, a centripetal tendency arises narrowing down the sphere of supply which is facilitated by the coming of many power oriented industries and their farflung industrial off-shoots and linkages near power sites. The sharpening of this pattern creates a well-defined hydro-power zone surrounded by a concentric zone of complementary thermo-power where many a thermo-power centre acquires a self generating force in time. In the run of this cycle, water resource, though runs on and runs smooth for sometime, will ultimately run to and run after the demand, when resources of thermo-powers will run up and run together to fabricate a pattern of power-mix-up in which hydro-power will appear as island in the expansive ocean of thermo-power.

13. De, Niranjan—Op.cit—pp. 27-31

14. Zimmermann—Op. at—p. 611.

15. Ibid . . . p. 611.

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GEOGRAPHY OF THE GROWTH OF ELECTRIC POWER IN WEST BENGAL

Dr. B. Banerjee

Abstract

West Bengal is pioneer in the field of electricity generation. It was here at Darjeeling that the first hydel plant of India was started in 1897 and the first thermal plant of the country was set up in Calcutta in 1899. During the first 50 years of its growth, the installed capacity of electric power of this State was increased to about 600 Mw. Growth rate in the subsequent years are more spectacular, recording an annual growth rate of 8 per cent during the said period. Such a rapid expansion in power production is due to the growth in demand of electricity in India.

Of the different sources of power used for the generation of electricity in the State, the thermal units are more numerous and cover about 90 per cent of her total generating capacity. The coal resources of the Damodar Valley region and the location of the collieries in (viz. Asansol-Durgapur region) or within the economic distance (viz. the CMD) from the consuming centres have helped in the growth of the thermal units of the DVC and CMD areas. Under the existing conditions, the thermal plants have been found to be more economical because of their locational flexibility. Recent technological improvements

in the use of low grade coal for thermal power generation, economic transmission of power by high voltage transmission lines and the mobility of the fuels have helped in widening the range of thermal plant sites.

In case of hydro-electricity, the locational factor is rigid and is often controlled by favourable terrain. As such, most of the hydel plants are located either in the Himalayan foot-hills or in the western plateaus. Hydro-electric development is poor in West Bengal (only 15 per cent of the potentialities have been harnessed so far) because of the high initial cost of installation of units and lack of immediate demand in the producing areas.

The pattern of power utilisation within the State shows that the industries are the bulk consumer of electricity (over 75 per cent), being followed by its use in domestic and commercial lighting. Demand of electricity from the railways is increasing but its use in irrigation is still very insignificant.

Experts are of opinion that West Bengal is likely to face a serious power shortage in the next decade. This necessitates the setting up of additional units like the million unit super thermal plant at Santaldih and also to explore other sources of energy like the use of nuclear energy or tides (from the southern rivers) for the generation of electricity. Future development should be based on co-ordinated planning and growth of an infrastructure on a regional basis.

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Introduction

The use of electric power is indispensable for modern civilisation. It is used extensively in agriculture, mining, industrial operations, commercial undertakings, waterworks and in railway tractions. Its use is often taken as an index to a country's prosperity. India's per capita consumption of electricity is 45 units as against 1270 for U.K., 1420 for U.S.S.R. and 4,400 for U.S.A.

West Bengal is pioneer in the field of power generation. The first hydel plant was set up here at Darjeeling in 1897 and the first thermal plant was installed in Calcutta two years later. Power generation was then taken up by other States.

Progress of Power Generation

During the first 50 years of its growth, the generation capacity was slowly increased. From a poor installation capacity of only 230 kilowatt in 1900, the amount was increased to 629,000 kilowatt in 1951. With the exception of the Calcutta Electric Supply Corporation, most of the generating units were small and privately owned. The Calcutta Electric Supply Corporation, with an installed capacity of 440 Mw was then the largest unit, claiming about 70 per cent of the entire capacity of the State.

The five year plans ushered in a spectacular rise in power generation so that in the course of the last 16 years, power production has been increased by about 130 per cent, thus showing an annual growth rate of 8 per cent. The growth of industries and expansion of urban areas created unprecedented demand for power. Expansion took place at the initiation of the State Government and the Damodar Valley Corporation. The generation capacity of Calcutta Electric Supply Corporation has also been substantially increased. The total installed capacity of West Bengal at the end of the

3rd plan was 1205 Mw which has since then been increased to 1711 Mw in 1968. This has made West Bengal, the largest consumer of electricity in India, her per capita consumption being 166 Kwh in 1967-68.

Sources of Power

Thermal Plants : Of the different sources of power used in the generation of electricity viz., coal, water, diesel oil etc., the thermal units are more numerous in West Bengal covering about 90 per cent of her total generating capacity. This is obvious because West Bengal has plentiful resources of coal. The two major industrial regions of this State, namely the Calcutta Metropolitan District (CMD) and Asansol-Durgapur region, are the maximum consumers of electricity. Of these two existing markets the second one is located within the Raniganj and Barakar coal fields and the other lies within easy economic distances from them. It is, therefore, obvious that these two regions share between themselves about 95 per cent of the total thermal power production of this State.

Under the existing economic set-up, the thermal plants have been found to be more economical because of their locational flexibility. Such locational flexibility in West Bengal may be attributed to several factors, like :

1) Plentiful resources of coal :—Coal production of West Bengal is about one-third of India's total output of about 70 to 75 million tonnes. The thermal plants consume only 10 per cent of the State output. The vast coal reserves of about 13,000 million tonnes occurring to a depth of 2000 ft. would also provide adequate fuel to the future thermal plants of the State.

2) Use of low-grade coal in power generation :—The reserve of high grade coal is very limited in West Bengal. The

thermal plants, however, use the low-grade coals which are unsuitable for metallurgical purposes. Hence it does not exert any strain on the fuel supply, rather it brings economy in its efficient utilisation.

3) Mobility of coal or diesel oil in thermal power generation :—Coal and diesel oil, the principal raw materials for thermal units, can be easily transported by railway wagons and tankers. Presently even low-grade pulverised coal is being economically brought to the generating units by means of conveyor belts as well.

4) Quick and regulated supply of power :—Thermal power can be generated more quickly and regulated according to market demand more efficiently than the hydel plants.

5) Cheaper to install :—The capital cost of installation is cheaper for small and medium-sized thermal plants than the comparable hydel units.

6) Recent technological progress has made lesser use of coal in the generation of electricity :—Formerly it took about 11 Kilograms of coal to generate one Kwh of electricity. The industries accordingly had to be located at or near the source of power. But this amount has now been reduced by half, thanks to the modern technological progress. As a result of this, location is now rarely decided by power factor alone as they are becoming more and more market oriented.

Hydel Plants : Power generation from hydel sources is poor in West Bengal, claiming only 9 per cent of the installed capacity under all the categories of electricity generating units. Prior to the plan period, there were only two small hydel units in operation at Darjeeling and Kurseong. The installation of new units at Maithon, Masanjor and Jaldhaka are significant steps taken during the plan periods.

In case of hydro-electricity, the locational factor is rigid and is often controlled by favourable terrain, high initial cost of setting up new generators and high maintenance cost of the transmission lines generally taken over from the hilly and rugged terrain. Because of these considerations, hydro-electric development is poor in West Bengal, only 15 per cent of her potentialities have so far been harnessed.

Most of the hydel plants of the State are located either in the western plateau or in the Himalayan foot hills. The western districts have limited potentialities because of the seasonal flow of the rivers, gentle slope and the necessity for the construction of costly reservoirs at the installation sites. Two units, one at Maithon (60 Mw) and the other at Masanjor (4 Mw) are in operation here. But due to the fluctuation of the reservoir level, power generation is hampered especially during the summer months. The Himalayan foot hills of the north, however, possess favourable geographical environment for setting up hydel units, like perennial river flow, steep slope, high rainfall and the location of the projected units within economic transmission distances of the potential load centres. But power development is insignificant because of their locations away from the major consuming centres of the State. Of a modest estimate of 1000 Mw hydel potentialities of North Bengal, a little over 20 Mw have been harnessed so far. Of the units, the Jaldhaka project has the capacity of 18 Mw.

Diesel Plants : Only an insignificant percentage, about 2 per cent, is generated from diesel sets. These units are small and widely scattered. A number of small and isolated municipal towns of Malda, West Dinajpur, Jalpaiguri, Murshidabad and Midnapur districts have electricity from their respective diesel plants.

Power Utilisation in West Bengal

Industries : The pattern of power utilisation in West Bengal shows interesting features. The different categories of industries

are by far the largest consumer of electricity, claiming about 77 per cent of the total consumption in 1966-67.

The substantial growth of load in the CMD and Asansol-Durgapur region is caused by the rapid proliferation of her industries, especially those which consume considerable quantities of power, like engineering, chemical, aluminium and electrical industries. The metallurgical, aluminium and the fertiliser factories are by far the largest consumer of power in Asansol-Durgapur region. Within the CMD, the largest consumers are the engineering units, chemical plants and textile mills.

Residential and commercial : Next to industries, the growth of demand is highest in domestic and commercial lighting. The increase of load in this sector is due to rapid rise of urban population, an improvement in the standard of living and gradual extension of electricity in the rural areas. At the end of the 3rd Plan, about 117 towns and 926 villages have been electrified. But the progress of rural electrification scheme is rather slow in West Bengal, because of the high installation cost and high unit rate.

Railway Traction : Growth of load in the Indian Railways has substantially increased in recent years. This is due to the programme of electrifying the railway traction with a view to conserve better quality coal rather than burning the same in steam locomotives and also to improve the flow of traffic in the industrial and urban regions.

Water supply and drainage : Water supply and drainage schemes and public lighting programmes are also using electricity in increasing volume. This growth may be attributed to the expansion of urban areas and along with it the extension of existing roads and shopping centres over newer areas.

Agriculture : In agricultural sector especially in lift irrigation or deep tube well schemes, the use of electricity is still insignificant.

Conclusion

Assessments made by the Central Water and Power Commission and the National Council of the Applied Economic Research reveal that West Bengal is likely to face a serious power shortage during the next 10 years or so. To meet up this immediate shortage the production requires to be at least doubled. This necessitates the immediate setting up of the proposed million Kilowatt super thermal power plant at Santaldih in Purulia district and further expansion programmes in the Damodar Valley and CMD regions. To meet up the immediate shortage, the best course is to set up coal-fired power stations of medium to large size. It is only in North Bengal that thermal power plants may be supported by a number of diesel and hydel stations.

In view of the fact that electric power is generally used for an all-round and balanced economic progress, the present and the future trend of development should be based on co-ordinated planning and growth of the infrastructure on a regional basis.

GEOGRAPHICAL IMPLICATIONS OF RURAL ELECTRIFICATION IN INDIA

S. C. Mukhopadhyay

Abstract

Introduction of the electricity to rural areas of India in the last twenty years has brought prosperity to sections of the country where only hardship was known before. Rural electrification has meant new jobs, better sanitation, more purchasing power and a high standard of living. It has been the driving force in a rural revolution and is one of the prime factors behind the location of small industries out of the crowded metropolitan areas. Most of the work has been done during a short period of 15 years under the three Plans. Particularly in connection with "grow more food" campaign the need for electrifying rural areas has been fully realised and highest priority is being accorded to it. Over 700,000, irrigation pumping sets are expected to be electrified under the Fourth Plan alone.

During the First and Second Five Year Plans 6,568 and 16,633 villages were electrified respectively. The Third Plan target of 20,000 villages has been exceeded by nearly 6,500 villages and for the Fourth Plan target of electrifying 57,700 villages has been under consideration. Today it is considered as one of the "musts" for the socio-economic development

of rural areas. It is interesting to realize that today about ten per cent of India's farms out of 5,67,000 villages have electricity (50% in some States) while only 0.6% had such service (3,700 villages) prior to the First Plan. It is not an over statement to say that the rural electrification in India is leading this country out of the "dark" ages.



Introduction of electricity to rural areas of some parts of India in the last 20 years has brought prosperity to sections of the country where only hardship was known before. Rural electrification has meant new jobs, better sanitation, more purchasing power and a high standard of living. It has been the driving force in a rural revolution. Now, it is allowing the city dweller and even the suburbanite a place to relax in comfort and is one of the prime factors behind the location of small industries out of the crowded metropolitan areas. Modern electric services to rural India has raised farm production and increased farm efficiency thus assuring urban people a plentiful supply of food and fibre at reasonable costs. The many back-breaking jobs which previously drained the lives of farm people have been eliminated through modern electric machineries. The concept of working from before sun-rise to after sun-down is no more. Now farmers have more leisure time than before to enjoy the fruits of their labour.

About 80 per cent of India's population live in 5,67,000 villages. All our efforts have to be directed towards achieving the economic development of these large number of villages in the shortest possible time.

Where similar conditions prevailed in most of the developed countries (like U.S.A. as for example) in earlier stages of their economic growth, experience has invariably shown that electricity plays a vital role in raising living standards in rural areas.

It has got a chain reaction. Naturally with the increased prosperity of the rural areas, other parts of the nation also have prospered. Every year now, crores of rupees of electrical appliances are purchased by rural electric consumers. As a result of this purchasing power, thousands of new jobs in city factories have been created to fill their needs.

Progress Under the Plans

However, rural electrification in India did not occur overnight; it came about through hard work and the vision of dedicated public figures.

Most of the work has been done during a short period of 15 years under the three Plans. Particularly in connection with grow more food campaign the need for electrifying rural areas has been fully realised and highest priority is being accorded to it. But the task is stupendous since only about 10 per cent of the 5·67 lakh villages have been electrified by the end of the 3rd Plan in 1965-66. On the basis of available figures it appears that only 3,700 villages (i.e. about 0·6 per cent) had been electrified, prior to the First Plan probably due to following causes.

To start with, the electricity supply industry was in the hands of commercial organisation, licensed under the provisions of the Indian Electricity Act, 1910. These organisations could not be persuaded to get interested in Rural Electrification because due to sparse distribution of rural demands and poverty of rural population, the returns from supply of electricity in rural areas are not adequate to meet even the bare running and maintenance charges. In varying degrees, these conditions have prevailed in all countries of the world. However, outside India, the importance of indirect benefits of rural electrification was realised as far back as in early thirties, culminating in measures for rendering active administrative, technical and financial assistance for the progress of rural

electrification by the Government. In India, however, a beginning was made only under the provisions of Electricity Act of 1948. This Act provides for rationalisation of production and supply of electricity and for adoption of measures conducive to electrical development of the various States through the agency of the State Electricity Board. It has, thus, become the responsibility of these Boards to arrange for supply of power to rural areas. As a result 6,568 and 16,633 villages were electrified during the First and Second Five Year Plans respectively. The Third Plan target of 20,000 villages has been exceeded by nearly 6,500 villages and for the Fourth Plan, a target of electrifying 57,700 villages has been under consideration. It is agreed that the rural electrification programme should be intensified during the Fourth Plan. The emphasis would have to be, however, on the energization of clusters of irrigation pumps keeping in view the ground water availability in various areas. The rural electrification programme should be dovetailed with the energization of such pump clusters. It was proposed to electrify 700,000 wells during the Fourth Plan period. If present trends remain constant, power demands in rural India will continue and rural electric systems must grow to meet these increased demands.

Rural Electrification for Food Production

Irrigation has assumed a special significance in our economy as food shortage is one of our major problems. By the end of 1962-63, 83·6 per cent of the cropped area was reported as without ensured means of irrigation and 12·75 per cent of cropped area only was reported as sown more than once. Increasing importance is being given to lift irrigation, particularly in those areas which are not covered by any major irrigation project. This may be understood from the fact that whereas up to the end of the Third Plan only 6 lakh (5·10 lakh) irrigation pumping sets had been electrified, over seven

lakh irrigation pumping sets are expected to be electrified under the Fourth Plan alone. To enable achievement of these targets, the supply of electricity for agricultural purposes is subsidised wherever the rate is higher than 12 paise per (unit) Kwh. Examples may be cited from the Soviet Union where agricultural rates were only one-fourth of those for domestic use of the U.S.A. where loans at two per cent repayable in 35 years were offered, and of France which loaned funds at three per cent with a repayment period of 40 years. Japan, Norway and Canada subsidised costs of installation of transmission lines and equipment to the extent of 30-50 per cent. A levy of up to half a percent was collected on sales of electricity in New Zealand and the proceeds were turned over for assistance to rural electrification.

It is necessary to bring about uniformity in the rates of power supply to consumers within a State irrespective of the source of power, whether hydro, diesel or thermal. In order to evolve as far as possible, a uniform practice, it has been recommended (by the Ministry of Irrigation and Power, Govt. of India) that a minimum consumption guarantee of Rs. 35 per connected horse power per annum might be fixed. The cost of distribution lines should not be charged to agricultural consumers. It should be noted that only one tenth (1/10th) of the wells (at present about 6 million wells, including tube wells, supplied water to about 25 million acres or about a fourth of the land under irrigation) are fitted with diesel or electric pumps. The Ministry of Irrigation and Power was of the view, that the pumping facilities should be increased by another (ten) 10 per cent i.e., to electrify 700,000 wells during the Fourth Plan period. This would enable the production of another 4 m. tons of food-grains, equal to the present annual deficit, and also double power consumption in rural areas and bring it up to ten per cent of the energy generated in the country.

Electric Co-operatives

It is agreed that one Rural Electricity Co-operative in each State should be formed as a pilot project which would be extended further. These co-operatives should be closely linked with the industrial processing co-operatives and would be complimentary to the activities of the State Electricity Boards.

By the end of the Third Plan, about 9.3 per cent villages in the country had been electrified, but not uniformly so throughout the country. While rural electrification was as high as 49 per cent in some States, it was as low as two (2) per cent in some other States. With a view to removing these disparities, efforts are being made to apportion the rural electrification schemes in such a way that the minimum percentage comes to at least 15 to 20 per cent villages in all States by the end of the Fourth Plan. There is no doubt that the pace of rural electrification will step up from year to year and the benefits of power supply extended to larger and larger areas until all the villages in the country are electrified.

I visited some rural areas of Burdwan district, West Bengal and observed that the introduction of electricity by D.V.C. has resulted in complete transformation of life. Today it is considered as one of the 'musts' for the socio-economic development of rural areas. While it can be economically used for lighting homes, energisation of pumps, supplying power to rural industries, its value for the social uplift of the people can hardly be over estimated. It has provided large scale employment opportunities through rural industries (e.g. cold storage, rice milling etc.). It tends to bring the conditions of life in villages to the level of town life. It is thus recognised as an important factor for developing rural economy and for stopping the exodus of people from villages to the cities.

In the context of the need for making up the national food deficit in the shortest possible time a number of conclusions

are made i.e. (1) To organise Rural Electricity Co-operatives for enlisting popular support and participation in spreading electricity to the countryside. (2) To devise the quickest and cheapest methods of supplying electricity to rural India. (3) To determine the principles which should govern the possibilities of manufacturing spares within the country.

Even with all the advances rural electrification has brought, there remains a great deal yet to be accomplished and the job of rural electrification is not complete. It is interesting to realize that today about 10 per cent of India's farms have electricity (50 per cent in some States) while below 1 per cent had (3700 villages, 0.6 per cent) such service prior to First Plan. It came about through hard work and materialised largely through the ingenuity of the Indian people. It is not an over statement to say that the rural electrification in India is leading this country out of the "dark" ages.

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THE EFFECT OF ELECTRIFICATION ON SOCIAL AND
ECONOMIC LIFE OF BOLPUR

Subhendugopal Bagchi

Abstract

The scope of my study for the present is the effect of electrification on socio-economic life of Bolpur. In an attempt to do that I have traced from the past the necessary conditions which urged for electrification in the area. Tagore was contemplating very seriously to bring about a thorough change in the art of living by introducing electrical energy in Indian home and country.

While touring in the West he saw the utility of it and the convenience it gave to women folk. After it was introduced in Bolpur since the forties, a sort of urbanisation took place. The impact of war made Bolpur a trading centre of rice. It began changing its rural economy. Collection spread with its emphasis on some. A sort of sophistication started. The establishment of various medical and educational institutions increased the demand for electricity. With its introduction marketing facilities also increased. Poor men got chance for selling their goods till late in the evening, adding to their income considerably. Electricity proves a boon for them. It also acts as a boon to those youngmen and women who prefer a better social life being active members of well

equipped clubs, where they read newspaper, exchange views, and prepare schemes for necessary social work for the good of the area around.

In this paper I have tried to throw light on the utilisation of power and the effect of electrification on social and economic life of Bolpur.



Not far from the spot, where to-day the West Bengal State Electricity House of Bolpur is situated, there is the famous elevated seat 'Châtimalâ' of Santiniketan, sitting upon which Maharshi Devendranath (that illustrious savant of the 19th century India and father of Rabindranath Tagore) lost in contemplation used to commune with God.

Probably every citizen of Santiniketan-Bolpur still to-day hears the voice of Tagore, whenever he goes to the House for his monthly clearing up of the dues incurred through the consumption of perhaps the greatest electrical convenience, electric light, one that is enjoyed by the most people; for it was Tagore as was usual for him, felt the urge of having it long long ago, as evident from his writings.

The urge for electrification

In a letter¹ while touring in the West, written to his gifted son Rathindranath Tagore, he conveyed that he chanced to come in contact with a lady, Madame Dina, who had then lost her husband who was an Indian. She was then in a mood to offer something as a gift to India in memory of her husband.

1. 'Chithipatra'—Ind part, page 94—letter written by Tagore to his son Rathindranath on the 5th September, 1930 while touring in the West.

She sought Tagore's advice regarding the choice of it. In reply Tagore advised her to offer that which she considered to be the most suitable from her own point of view. Light and water, the two words, the two vital needs of our country immediately flashed through her mind. Tagore's keen awareness about these two things for the welfare of the country can be seen in his own utterance in the same letter. "Sudhu yadi Jal Alo pāi tāhale ār kichu nā peleo ebāre āmār āsā sārthak habe" (my visit to Europe will be, I feel, a success if I can have just light and water). It may be noted here that Tagore was deeply thinking not merely of his institution but of the country as a whole in this regard. This becomes evident from the fact that Santiniketan was electrified in the year 1916 though on a small scale (as recorded by Sri Prabhat K. Mukhopadhyaya in 'Rabindra Jibani' page 28, 3rd part). His talk with Madame Dina in 1930 shows that he was still thinking of the problem of electricity.

I have been staying in Bolpur since 1958. I note with wonder how the town of Bolpur with a semi-urban complex has been changing its form and character too fast. The forces of change started operating much earlier. The causes and nature of the change have found adequate expression in the following lines of Prof. N. K. Bose.²

"During the first world war, the price of rice mounted high, and Bolpur was consequently raised from its position of a small market to one of countrywide importance. Mills where paddy was husked were established in rapid succession, paved roads stretched across the country in all directions, the number of bullock carts increased, and Bolpur was eventually converted into one of the most important centres of rice trade in Bengal. By and by other railway stations like Gushkara, Ahmadpur or Sainthia also gained in importance; but Bolpur has succeeded in remaining at the head of the towns of trade".

2. Modern Bengal—page 32, by Nirmal Kumar Bose, Published by Monomohan Mukherjee, 72, Mahatma Gandhi Road.

The above facts undoubtedly have a bearing on our topic in so far as they make it clear about the growing need for electrification of Bolpur and its surroundings.

The urge for electricity emerged from the idealist's vision—it took shape and form ; it moved through the electrical wires in different directions of the town with its neighbouring villages like Trisulapati, Bandhgora etc. Growing urbanization of Bolpur made it a dire necessity. Electrification was started here by a private company in 1945. Subsequently it was taken up by the West Bengal State Electricity Board in the year 1953.

The Benefits derived

While reviewing it one may make a study of change in the pattern of the socio-economic life of the area concerned. In Bolpur-Santiniketan area the change in the concrete is not so pronounced as it is in the abstract. If anybody observes carefully he will find that the electrical energy has not been utilised so much in the small scale industry sector as it has been in making life more comfortable, more pleasurable, more aesthetically oriented. The educational institutions have benefitted by it. Owing to an ever-increasing emphasis on science and technology as dictated by our National Education Policy the various educational institutions have become major consumers of this energy. They all need huge quantities of running water whose machines are electrically operated. Electricity has helped the suffering humanity by helping the establishment of X-Ray clinics (two in Bolpur and one in Santiniketan), Pathological Laboratories (two in Bolpur and one in Santiniketan), a nursing home, an eye-hospital. Besides these, there are electrically operated petrol pumps, spray painting works and there are also a few rice mills which depend on electricity. Recently a toy-making industry, two grill-factories and one electro-plating workshop, all using electricity, have been established. All are located in Bolpur.

While reviewing the contribution that electrification has made to Bolpur one cannot afford to ignore the facilities it has offered in respect of marketing of perishable goods like fish etc. Due to better lighting arrangements the less established or poor fishermen who fish in the tanks, ponds or 'nullahs' of Bolpur, find it convenient for them to sell their goods in the market till late hours in the evening, even devoting the entire day to fishing and related occupations. They still have time to market their produce extending late into the hours of night. As they cannot afford to take advantage of cold-storage system, they really get benefitted by better lighting arrangements in the market. This has helped also those who sell vegetables. The blessings of electricity become evident when one notices the young men and women of the town attending their night classes of the Bolpur College Commerce Section and at the same time earning a living in day time. When one notices the uninhibited steps of the women folk proceeding either towards the shop or an educational institution or to the parties in the evening hours one realises that electricity has made men and women of this generation more modern and less conservative than their counterparts of the previous generation.

In spite of all these it should be noted that electrical wires have not gone much beyond the limited area of the town. It should cover up many more miles, it should illumine many more cottages in the outskirts of Bolpur-Santiniketan.

Tagore warned us years back against a system that³ makes the chosen few in towns the privileged class enjoying all the modern amenities of life. They are only enlightened against the background of a full eclipse of the poor and ignorant masses in the countryside. It is hoped that this will not be the picture of future India.

3. 'Rabindra Rachanāvali'—the eleventh volume, page 691, Rabindra Janmasatavāṛṣik Saṃskaraṇ (Rabindra Centenary edition).

ECONOMIC DEVELOPMENT OF UTTAR PRADESH IN RELATION
TO ITS POWER DEVELOPMENT

A. K. Bandyopadhyay

Abstract

Uttar Pradesh, the most populous state of India, is suffering from the "Stagnation of Economy". It reflects all the problems of under-development in an acute form.

The economic structure of the State is highly dependent on agriculture. Industrial sector of the State's economy is poorly developed which is again largely dominated by cottage and small scale industries. Despite the abundance of human resources and fertile agricultural and industrial development both suffer from lack of power.

Uttar Pradesh suffered from acute power shortage during the first two plan periods. In 1959-60 the per capita consumption of electrical power in the Uttar Pradesh was only 12.81 Kwh. However, after all the achievements of subsequent years and the Third Plan the State figure rose to 29.9 Kwh. Installed capacity at the end of the Third Plan was 910 Mw which is expected at the end of the Fourth Plan to be 1,427 Mwh. Efforts are also being made to set up a nuclear power station in the state.

The concentration of generation in large power stations and the development of regional

grids connecting them and the principal load centres by extravoltage lines are in the forefront of power development plans. During the Fourth Plan, it has been proposed to develop 4,500 circuit Kms. of main transmission line of 220 Kv and 400 Kv. The introduction of 400 Kv system will be for the first time in the country. The inter State power transmission is also in the progress.

During the last phase of the Third Plan, the programme of energisation of private tube wells and pump sets were undertaken. It has been proposed to electrify 1,25,000 pump sets in the Fourth Plan.

The thermal generation is predominant in the State and the cost of power generation is very high. The State is comfortably placed in the matter of hydro potential, and proper efforts are to be made to harness the hydel power.

People all over the State now are conscious about the benefits of electrical power and from the every corner of the State there is cry for power even from the rural areas. With the optimum utilisation of the power potentialities and extension of services all over the country, especially in the backward eastern districts of the State which is suffering from chronic power shortage, the economic growth of the State will be increased to a considerable extent. The days are not far off when the State of Uttar Pradesh will not be considered as one of the poorest states of India.

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The State of Uttar Pradesh is the cradle of cultural India. Throughout the history its impact in the country's affairs has been very pronounced. It is the state where Hinduism, Buddhism and, later Islam flourished in all their glory and radiated their influence to other parts of the country. The importance of the state in the country lies in its size, strategic position and its being the most populous state of India. Yet it is a cruel fact that, even after the completion of three planning periods, Uttar Pradesh today is one of the poorest states in India. It reflects all the problems of under development in an acute form.

General Economic Set-Up of Uttar Pradesh

Structurally, the economy of Uttar Pradesh is highly dependent on agriculture. More than 75 per cent (1961) of the working population of the state are engaged in agricultural activity. In spite of the perennial rivers, fertile Gangetic soil and the country's oldest irrigation system, the Gangetic plain of Uttar Pradesh yields are pitifully low and reduce the economy to a bare subsistence level. Total income of Uttar Pradesh from the agricultural sector was Rs. 1118.24 crores or 63.1 per cent of the total income as compared to 48.5 per cent for the country as a whole in 1960-61. The secondary sector where normally the productivity per person engaged is much higher, has been relatively backward in this state. The share of state's income originating in the Industrial sector is only 9 per cent as against the all India figure of 19 per cent. It is important to mention here that the industrial sector of the state is largely dominated by low value adding cottage and village industries. For example, in 1960-61 the contribution of large and medium industries in the total industrial output of the state was only 48 per cent as compared to the all India average of 57 per cent. The sectoral contributions to the total state income (existing and expected) are given in the following table :

Table 1

Total State Income
(in percentage) (1960-61 to 1970-71)

Sector	1960-61	1965-66	1970-71
1. Agriculture	63·20	60·07	53·00
2. Industry & Mining	9·10	10·69	14·80
3. Transport & Commu- nications	12·68	13·69	15·50
4. Other services	14·94	15·45	16·70
5. Total	100·00	100·00	100·00

Source : Industrial Programmes in Uttar Pradesh during Fourth Plan—Directorate of Industries, Uttar Pradesh.

The National income during the first three plan periods has grown at an average rate of 3·5 per cent per annum, whereas the corresponding rate of growth in Uttar Pradesh has been below this average and during the Third Plan the expected growth rate was 3 per cent only. There is a large and growing disparity in per capita income between the national average and that of the state, which is quite undesirable. If a large area of the country, with nearly 17 per cent of the total national population continues to remain as under-developed as Uttar Pradesh is at present, it is bound to have serious repercussions on the overall growth of national economy.

The progress of urbanisation in Uttar Pradesh is much slower than Indian average. In 1961, only 12·8 per cent of the states' total population lived in urban areas compared to 18 per cent of the country as a whole.

The entire state of Uttar Pradesh is economically backward ; and again within the state there is great regional

disparity from the point of income, industrialization, urbanisation and other economic indicators, with the result that some of these regions are among the poorest in the country. Among all the districts of Uttar Pradesh the Eastern and Northern districts are most backward in all respects. The percentage of urban population and per capita income in the Northern and Eastern Uttar Pradesh are 12.1 per cent and 7.4 per cent (1961) respectively and Rs. 284 and Rs. 229 (1955-56—N.C.A.E.R. estimates) respectively. In some districts of eastern Uttar Pradesh the percentage of urban population is only one per cent of the total population.

The economy of Uttar Pradesh is largely dependent on agriculture. Despite the abundance of man power and fertile agricultural tract, the state has at times failed to grow enough even for her own needs not to speak of feeding other parts of the country. It has been rightly remarked by Mr. S. K. Jain, Chairman, U.P. State Electricity Board, "By far the state has remained power starved. Every corner of the state is now crying for more and more power driven irrigation facilities."

The economic prosperity of a country is, however, judged today by the amount of electricity it consumes. In 1959-60 the per capita consumption of electrical power in Uttar Pradesh was only 12.81 Kwh—that is just enough to keep an ordinary heater going for about twelve hours. As against this the all-India average was 28.94. In comparison the state's figure was only 44 per cent of the country's average. The relatively lower energy consumption shows the economic backwardness of the state. However, after all the achievements of subsequent years and the Third Plan, the state's figure rose to 29.9 Kwh while that of the country to 60.89 Kwh. Although the state's consumption rose from 12.81 Kwh to 29.9 Kwh and its ratio from 44 per cent to nearly 50 per cent, in the order of per capita consumption, the state still stands almost at the bottom. In 1959, the installed capacity in the state was 355 Mw and this rose to 910 Mw by the end of the Third Plan and today it is 1187 Mw. How insufficient is this

capacity can be visualised by the fact that it will only suffice to run at a time about one lakh motors of average size.

The above explains why the progress of the state has been so scanty in the past. Without power there is no progress.

Power Development in Uttar Pradesh

The history of power development in Uttar Pradesh has been slow and chequered. Most of the generating stations were privately owned to serve the needs of major urban centres. Rural areas were absolutely neglected on account of the rural schemes being uneconomical. In the field of power, the objective is to carry the benefits of electricity to the people for use in industry, irrigation and daily domestic life. In the course of planning, construction or operation of power projects is guided by the social needs and objectives.

The development in the field of power in Uttar Pradesh first took place in 1903 when a small hydro-electric power station was commissioned to electrify Mussoorie town. The Indian Electric Supply and Traction Company, the predecessor of the Kanpur Electric Supply Corporation was set up by some European merchants in 1906 in Kanpur city. The history of power development in Uttar Pradesh thereafter was extremely slow. The total growth in installed capacity over nearly half a century was only 178 Mw when the process of planned development commenced in the country in 1951-52. During the first and second plans too, power progress was not encouraging.

The state of Uttar Pradesh is very comfortably placed as far as Hydro-Electric potentialities are concerned. It has been estimated by C.W.P.C. at 3.764 million Kw at 60 per cent load factor, distributed fairly evenly along the northern and southern mountain ranges bordering the state and on the Himalayas the potentiality is still higher. As the realisation of the

importance of power in the economic development increased gradually in the first decade of Independence, the power sector gained greater importance. To rationalise the production and supply of electricity and for taking measures regarding power development in the country, the Electricity (supply) Act 1948 was enacted by the government of India. Under the act the Electricity Boards were constituted in various states and Uttar Pradesh State Electricity Board was formed in April 1959. The total installed capacity when the Board took over charge was only 355 Mw and the total number of electrified localities were only 157. Since considerable strides have been made by the State Electricity Board and the power supply position of the state has improved to a considerable extent. As a result of planned development the State Electricity Board had on March 1960, an aggregate power plant capacity of 378,000 Kw made up of 93,000 Kw (25 per cent) from 9 hydel power stations, 250,000 Kw (66 per cent) from about 16 coal fired Thermal Stations, and the balance of 35,000 Kw. (9 per cent) from a series of diesel installations scattered all over the State. Remarkable development took place during the Third Five Year Plan when the states's installed capacity rose more than two-fold.

The planwise developments of power in Uttar Pradesh
are given below :

1. Installed Capacity at the commencement of First Five Year Plan	178.54 Mw
2. Installed capacity at the end of the First Five Year Plan	263.00 Mw
3. Installed capacity at the end of the Second Five Year Plan	378.00 Mw
4. Installed capacity at the end of the Third Five Year Plan	910.00 Mw

The following major Power Stations during First Five Year Plan were commissioned. The installed capacity of each Power Station has been indicated against each.

1. Khatina (Hydro-Electric)	41.4 Mw
2. Pathari (Hydro-Electric)	20.4 Mw
3. Mohammadpur (Hydro-Electric)	9.3 Mw
4. Kanpur Thermal Power Station Extension	15.0 Mw

The following Power Stations during Second Five Year Plan were commissioned. The installed capacity of each Power Station has been indicated against each.

1. Kanpur (Thermal)	15.0 Mw
2. Mainpuri (Thermal)	10.0 Mw
3. Sohawal (Thermal)	15.0 Mw
4. Gorakhpur (Thermal)	15.0 Mw
5. Mau (Thermal)	15.0 Mw

The following Power Stations during Third Five Year Plan were commissioned.

	Installed capacity (in Mw)	Installed capacity commissioned during 3rd Plan (in Mw)
1. Yamuna Hydel Scheme Stage I	84.75	56.5
2. Matatila Hydel Scheme	30.0	30.0
3. Rihand Hydel Scheme (transferred from Govt.)	300.0	300.0
4. Kanpur Extension of R.P.H.	15.0	15.0
5. Harduaganj Stage I	60.0	60.0
5. Harduaganj Stage II	30.0	30.0
7. Muradnagar Gas Turbine	12.5	12.5

In spite of these achievements the State remained very much behind the all India average. The installed capacity even after the achievement of the Third Plan, was only about 10 per cent of the country's installed capacity.

The Uttar Pradesh State Electricity Board recently conducted a survey to make an accurate assessment of the State's power demand in the next few years. According to the Survey it has been found that in the winters of 1967-68 the maximum demand will be 712 Mw and this is again anticipated to grow to more than 900 Mw in the winters of 1968-69. The Board expects a simultaneous maximum demand of more than 2600 Mw by the end of the Fourth Plan. Installed capacity by the end of Third Plan was 910 Mw and additions of 276.50 were made during 1966-67 and 1967-68. The additional installed capacity of 276.50 Mw achieved during 1967-68 has been made up by the following :

	Installed capacity (Mw)
1. Obra Thermal	100.0
2. Harduaganj Thermal Stage III	50.0
3. Panki Thermal	64.0
4. Renukoot Thermal (Private Sector)	62.5
Total	276.5

The installed capacity has thereby been raised from 910 Mw to 1,187 Mw by the end of 1967-68.

In the annual plan for the current year (1968-69) installed capacity of 240.75 Mw have been proposed. Details of addition envisaged in the installed capacity are :

	Installed capacity (Mw)
1. Obra Thermal	100.0
2. Harduaganj Stage III	50.0
3. Yamuna Stage I	28.5
4. Renukoot Thermal (Private Sector)	62.5

The installed capacity at the end of the Fourth Plan is therefore expected to be 1,427 Mw. Anticipated per capita consumption by the end of the Plan is expected to be 100 Kwh. In fact even with a plan of this size a severe shortage of about 500 Mw of power by the end of the Fourth Plan will still remain. Efforts are also being made to set up a nuclear power station of 1,000 Mw capacity in Uttar Pradesh to make up the back log and to further augment the generation capacity.

Transmission Network in Uttar Pradesh

The concentration of generation in large power stations and the construction of regional grids connecting them and the principal load centres by extra high voltage lines are in the forefront of power development plans.

At the end of the Second Plan there were only 2,000 circuit Kms. of main transmission lines (66 Kv and above) in Uttar Pradesh. In the Third Plan as many as 2,268 circuit Kms. of main lines were added raising the total length to 4,268 circuit Kms. The pace of development has been further increased and it is anticipated that by March 1969 there will be as many as 8,374 circuit Kms. of main lines (66 Kv and above) spreading over the entire State. The transmission

system has been extended to a large number of new load centres and a vast area of eastern Uttar Pradesh which was not on the electrical map only a few years ago is now getting the benefits of electricity.

During the Fourth Plan it has been proposed to add another 4,500 circuit Kms. of main transmission line of 220 Kv and 400 Kv. The new lines will include a 220 Kv single circuit transmission line linking Moradabad with Harduaganj and another similar line on double circuit towers from Kanpur to Lucknow. These lines will help to meet the rapidly rising load demands in Moradabad-Bereilly and Lucknow-Sitapur-Shahjehanpur area. Another single circuit line of 220 Kv will be constructed from Sultanpur to Gorakhpur and will meet the increasing power demand in Gorakhpur-Mau area. The introduction of the proposed 400 Kv system will be for the first time in our country. A 400 Kv single circuit transmission line will be constructed from Obra (Thermal) to Lucknow via Sultanpur. This 400 Kv line will be the first link in the formation of a regional and later on an all India power grid. Apart from these, a large number of 132 Kv and 66 Kv lines will also be constructed during the Fourth Plan.

In Uttar Pradesh, with the development of transmission facility, two major power generation complexes are gradually coming up, one on the South Eastern Uttar Pradesh and the other on the North Western Uttar Pradesh. In the former, Hydro Electric generation to the tune of 300 Mw. (Rihand) is already available and another 100 Mw. from Obra (Thermal) will be added in near future. Besides, there are sizeable coal deposits (2.5 million Tonnes) at Singrauli and accordingly there is a bright scope for setting up a super Thermal station at Obra area where at present a 550 Mw. power station is already installed. This is therefore likely to develop into a big power generation complex. Similarly the North Western Uttar Pradesh is very comfortably placed in the matter of hydro potential, which is being progressively harnessed to develop a big complex in this area. A number of hydro electric Scheme

like the Yamuna complex Schemes, Maneri Bhali, Lakhwar and Byasi etc., are either already being constructed or are planned for construction in near future. A gigantic scheme of 1000 MW or more at Tehri are also contemplated in this area and thus a very big hydro-electric generation complex will be developed in this area in near future.

As the above mentioned two generation complexes will be developed at a distance of more than 1000 Km. and the load centres lie between the two it will be necessary to interconnect these two power complexes in between themselves as well as with the major load centres of the State. For this purpose it has been proposed to extend the proposed 400 Kv line upto Rishikesh via Moradabad during Fifth and Sixth Plan period. For the purposes of Planning the power projects on a regional basis sometimes inter State power grids are also developed. It is not always possible that adequate power potential be found to the required extent within the respective state boundaries.

In Uttar Pradesh, one such links, a 220 Kv single circuit line will be constructed between Shamli and Panipat to inter connect Uttar Pradesh with Haryana and Punjab power systems. The other inter state link is proposed to be set up between Uttar Pradesh and Bihar (D. V. C. systems) and will connect Mughalsarai with Gaya via Dehri. A 132 Kv single circuit line from Dhakrani in Uttar Pradesh to Giri in Himachal Pradesh, single circuit line of 132 Kv from Mathura to Bharatpur in Rajasthan and another 132 Kv single circuit line from Etawah to Gwalior in Madhya Pradesh have been proposed. The Madhya Pradesh Electricity Board, which has about 150 Mw of surplus power will supply 40 Mw to Uttar Pradesh from Amar Katak power station. Uttar Pradesh will supply to Madhya Pradesh 5 MW. of power from Rihand project for distribution in the Sidhi district, a chronic drought area, to meet the power requirements of minor irrigation schemes.

Electrification of Rural Areas

The shifting pattern of population from one area to other can be directly attributed to the strata of energy in the area on which the economic developments depend to a considerable extent. The urban areas have a concentration of energy both in producing and utilising sectors and have always attracted persons from the areas lacking in power. Persons in search of areas for industrial development and better life have always migrated to the urban areas from the neighbouring rural areas. It is also the backward economy of the rural areas which has always pushed the persons to the urban areas. It is the falling rate of production and per capita income which have brought the sense of insecurity among the ruralities. Everywhere in India the rural areas have remained very backward and in the case of Uttar Pradesh the problem is most acute.

As per 1961 census there are 1,12,624 villages in the state. Of these 16,227 are with a population of 1,000 and above and 26,015 with population between 500 to 1,000. In 1958-59 there were only 157 electrified localities in Uttar Pradesh.

It has been stressed earlier that the economic structure of Uttar Pradesh is largely based on agriculture, and the future developments of the State are also associated with it. Strangely enough that no proper attention has yet been paid for the mechanisation of the irrigation system of the State. Despite the State is rich in man power and fertile agricultural lands, the State has at times failed to grow enough food. By far, the most important reason is that the State has remained power starved, specially the rural areas. The entire agriculture depends on the waters of the monsoon and whenever there is lack of rain the production of crop suffers. The drought of 1967-68 has made the Government conscious about the extension of power in the rural areas and to energise the wells for irrigation purposes. Every corner of the State is now crying for more and more power driven irrigation facilities.

The progress of rural electrification had rather been unsatisfactory till the first two Five Year Plans. It was only during the last phase of the Third Plan that the programme of energisation of private tube wells and pump sets were undertaken in some sizeable scale. There were only 4,554 private tube wells and pump sets energised in the State at the end of March 1965. By the end of the Third Plan there were besides 7,675 electrified state tube wells, only 9,283 private tube wells and pump sets electrified in Uttar Pradesh as against 2,56,098 in Madras. Though Uttar Pradesh is the most populous State of India it had only 3.3 per cent of the total electrified tube wells of India against 50 per cent of Madras. Work was completed on 19,619 private tube wells and pump sets in 1966-67 and on 16,946 in 1967-68. Besides 432 new State tube wells were electrified during 1966-67 and 321 during 1967-68 bringing the total of energised state tube wells by the end of 1967-68 to 8,428.

The number of electrified localities increased to 4,810 by 1967-68. To extend electricity facilities to a larger area, which is deprived at present, over 3,000 more villages have been proposed to be electrified during the Fourth Plan. It has been proposed to electrify 1,25,000 pumping sets (besides 25,000 connections under deposit Scheme) in the Fourth Plan commencing from 1969-70. It is further proposed to give connections to 10,000 rural consumers (other than tube wells, and pump sets) to help industrial development in rural areas.

Conclusion

“Uttar Pradesh’s Economy Stagnating”—is the present day cry of the State. Although some efforts have been made in the State since Independence to promote the growth of industries and agriculture and as such the economy, the results have not been encouraging. Uttar Pradesh’s per capita income has been continuously sliding downwards and her economy has been stagnating. It is therefore essential not only to arrest this falling trend but to boost up the economy

in such a manner that the per capita income of the State at least equals the national average.

Nature in the chance of shuffling its resources has deprived the State as far as mineral resources are concerned. Fortunately the State is blessed with the vast tracts of fertile agricultural lands. As has been stated earlier the economic structure of Uttar Pradesh is highly dependent on agriculture. To a significant extent there is a lack of adequate industrial development. Situated as it is, this State will have to continue to depend to a relatively larger extent on agricultural productions. However, it is recognised that the growth of agriculture and economic development of Uttar Pradesh alike hinge upon advance made by industry. In all developments, agriculture and industry have to be regarded as integral parts of the same process. A strong forward push to the State's economy should come from the expansion of the industrial sector also. Agricultural and industrial developments must go on *pari-passu*. An increased tempo of industrialization takes place only if certain basic facilities and incentives are made available of which, adequate supply of power at an economic rate is one of the essential factors. Development of industry in the past has been largely determined by the availability of power. Uttar Pradesh was short of electric power during the first two plan periods and this retarded the industrial growth. To increase the agriculture production the major irrigation facilities are to be extended to a considerable extent. Though something has been done for the electrification in rural areas still major part of this gigantic work is left. In fact in the present trend no progress whether industrial or agricultural is possible without adequate electrical power. It has been rightly remarked by P. S. Lokanathan (Techno Economic Survey of Uttar Pradesh) that notwithstanding the fact that the State's economy has been stagnant for a long time, it is more than possible to give a strong jerk to it and release the forces of growth which should lift its agriculture from its present morass and, at the same time, create a strong and stable industrial base.

There is no balanced development in the State. It is well known that the eastern districts of Uttar Pradesh are chronically lacking in all types of development. Until recently the major part of eastern Uttar Pradesh was not in the electrical map of the State. The urgent task of the government is to reduce this regional imbalance.

At present, about 60 per cent of the State's total installed capacity is thermal and the rest hydel. As thermal generation is predominant in the State, the cost of power generation is very high and so the electricity rates are very high in the State. The high rate of power in the State are no doubt crippling industrial growth. Recently the electricity charges have been increased significantly. It has given deadly blow to the existing industries all over the State. The State is comfortably placed in the matter of hydro-potential. On the other hand the State is lacking in coal reserves, the coal is found only in Singrauli with an estimated reserves of 2.5 million tons. So proper care is to be taken to harness the abundant and relatively cheaper sources of hydel power available in the State. More and more suitable hydro-electric schemes are to be initiated and planned.

Present civilisation owes its existence to the utilisation of power. In today's world electricity has become an indispensable one. Modern developments in all fields demand more and more power. The attraction for electricity has now caught the imagination of the rural population even—not only for domestic purposes but also to irrigate their lands, so that they are no longer left to the mercy of the monsoon. It is power which will lead the country in achieving self-sufficiency in food and prosperity. In every corner of the country now there are clamour for power and more power. The hunger for electricity is to brighten the world and lighten the man's burden.

PLANNING OF POWER PROJECTS

D. K. Bose

Abstract

The paper discusses some methods of planning for investments on power projects.

Three different types of problems relating to the planning of power projects are presented in the paper. The first problem concerns a plan for a relatively short period where the technological coefficients of production, the pattern of demand for power and the investment budget are given once for all. The second problem takes a longer period of time as the planning horizon when technological progress permits consideration of advanced techniques in the later periods. In the third problem, the demand for power is determined through a recursive relation; the demand for power in the current period is influenced by the interaction of the supply with other sectors of the economy in the previous period. Techniques of linear programming are used to analyze the solutions to the problems.

Planning of Power Projects

The methodology of optimal investment policy holds a central position in the literature on planning. It is intended

to bring some of the experiences of the economists and operation researchers to the attention of the scientists engaged in other fields in this paper.

Three different types of problem relating to the planning of power projects are chosen for presentation here. The first problem concerns a plan for a relatively short period where the technological coefficients of production, the pattern of demand for power, and the investment budget are given once for all. The second problem takes a longer period of time as the planning horizon when the technological progress permits consideration of advanced techniques in later periods. In the third problem the demand for power is determined through a recursive relation where the demand for power in the current period is influenced by the interaction of the supply with other sectors of the economy in the previous period.

Success in the planning of power projects depends on a proper combination of economic and engineering considerations. The economist receives from the engineer technological data describing the relationship between the inputs and outputs for alternative ways of producing the same thing. It is the task of the economist to choose the best among these alternatives with the aid of given economic and other considerations.

The usual way for an economist is first to define a production function expressing the relationship between the inputs to a productive system and its outputs by an equation like

$$f(x_1, \dots, x_n, y_1, \dots, y_m) = 0$$

$$\text{or, } f(x, y) = 0$$

where n different inputs produce m different items of outputs, x_i being the quantity of the i th input and y_j , the quantity of j th output.

The output vector y^0 , belonging to production function $f(x^0, y^0)$, is considered to be efficient if there is no other y larger than y^0 for the given input vector x^0 , nor can there be any other x less than x^0 producing same output y^0 . The production function then describes a locus of points (x, y) such that any point (x^0, y^0) on the locus is efficient, or superior, to point not on the locus.

The planning for production involves the choice of a suitable point (x, y) from among those belonging to the efficient set. The criterion for such a choice is determined by the objective of the planners. A scalar-valued function of input-output vectors, say $u(x, y)$ is therefore formed so that one can unambiguously choose a plan with higher values of $u(x, y)$ as more desirable than those with lower values.

$u(x, y)$ may be taken to be the net-benefit function associated with the productive projects available for selection. Let

$$u(x, y) = \sum_j p_j y_j - \sum_i p_i x_i$$

where the i th input to a project has an average value of p_i and the j th output an average value of p_j per unit. p_i 's and p_j 's may either be constants or functions of (x, y) as necessary.

The objective of the planner would be to maximize the net benefit subject to the constraint that the plan be on the locus of efficient points indicated by the production function. Using the Lagrangian function

$$L(x, y, \lambda) = u(x, y) - \lambda f(x, y)$$

where λ is an undetermined Lagrangian multiplier, the necessary conditions for the maximization of the net benefit function are obtained as

$$\frac{\delta u}{\delta x_i} / \frac{\delta u}{\delta y_j} = \frac{\delta y_i}{\delta x_i}$$

$$\frac{\delta u}{\delta x_i} / \frac{\delta u}{\delta x_h} = \frac{\delta x_h}{\delta x_i}$$

$$\frac{\partial u}{\partial y_i} / \frac{\partial u}{\partial y_k} = \frac{\partial x_k}{\partial y_j}$$

The optimality conditions indicate,

(1) that marginal increase (or decrease) in the j th output corresponding to marginal increase (or decrease) in the i th input, which is the marginal productivity of i th input when devoted to j th output, should equal the ratio between the changes in the net benefit functions due to changes in the i th input (that is its cost) and the j th output respectively ;

(2) that the marginal rate of substitution of the h th input for the i th input should be equal to the ratio between the marginal cost of the i th and the h th inputs ;

and (3) that the marginal rate of transformation of output k for the j th output should equal the ratio between marginal net benefits derived from them respectively.

The above analysis proceeds on the assumption that the planners are not fettered by any constraint on the resources available for the plan. In practice, however, the budgetary constraint imposes an overriding limit for a plan. It is therefore more realistic to consider the optimality problem with due regard to the limitation in the availability of the resources.

The problem of optimality conditions in project planning subject to, the limitations of financial resources (and sometimes additional limitations on factors of production) has been the subject of intensive analysis in recent literature [1 — 5]. We follow Marglin (5) in formulating a problem in project planning.

The objective of the planning authority is to look for the set of design for the the systems $s=1, 2, \dots, S$ which maximises the net benefit function.

$$\sum_{s=1}^S \sum_{q=1}^Q \theta_q \left[E_{sq}(y_{sq}) - M_{sq}(x'_{sq}) \right] - \sum_{s=1}^S K_s(x_s^0)$$

subject to the production relations given for each of the systems by

$$f_s(x_s^0, x'_{sq}, y_{sq}) = 0 \quad \begin{matrix} s=1, \dots, S \\ q=1, \dots, Q \end{matrix}$$

and subject to the constraint on the overall construction cost

$$\sum_{s=1}^S K_s(x_s^0) = \bar{K}$$

where $\bar{K}$ is the given level of the construction budget and where the following significance is attached to the symbols used

$E_{sq}(y_{sq})$ = efficiency benefits from y_s th product at q th period

$M_{sq}(x'_{sq})$ = OMR* costs for x'_s th variable input at q th period

$K_s(x_s^0)$ = cost of x_s^0 th fixed input at 0th period

θ_q = discount factor for q th period

The general problem of optimization tackled by separating out, at the conceptual level, the problem of design from the problem of the allocation of the budget for the different systems.

It is assumed in the first instance that the overall budget has been distributed, following some criterion of optimality into sub-budgets for individual systems. The attention is now focussed entirely on the design problem for each system where the objective is to maximize the net benefit function.

$$\sum_{q=1}^Q \theta_q \left[E_{sq}(y_{sq}) - M_{sq}(x'_{sq}) \right] - K_s(x_s^0)$$

subject to $f_s(x_s^0, x'_{sq}, y_{sq}) = 0$ and $K_s(x_s^0) = \bar{K}_s$

* OMR—Operation, maintenance, and replacement

where $\bar{K}_s$ is the amount allocated as the sub-budget for the sth system.

Introducing a simplifying assumption that the volume of products y_{sq} supplied, and hence the efficiency benefits $E_{sq}(y_{sq})$ derived from them, are constant over $q=1, \dots, Q$, the Lagrangian expression for maximization becomes

$$L = \theta [E_s(y_s) - M_s(x'_s)] - K_s(x^0_s) - \mu f_s(x^0_s, x'_s, y_s) \\ - \lambda [K_s(x^0_s) - \bar{K}_s]$$

$$\text{where } \theta = \sum_{q=1}^Q \theta_q$$

$$\frac{\partial L}{\partial y_{sj}} = \theta (\partial E_s / \partial y_{sj}) - \mu (\partial f_s / \partial y_{sj}) = 0$$

$$\partial L / \partial x'_{si} = -\theta (\partial M_s / \partial x'_{si}) - \mu (\partial f_s / \partial x'_{si}) = 0$$

$$\partial L / \partial x^0_{si} = -(\partial K_s / \partial x^0_{si}) - \mu (\partial f_s / \partial x^0_{si}) - \lambda (\partial K_s / \partial x^0_{si}) = 0$$

Transposing the expressions and substituting suitably, we can derive the relations

$$\theta \partial E_s / \partial y_{sj} / (1 + \lambda) = \frac{\partial K_s}{\partial x^0_{si}} = - \frac{\partial f_s / \partial y_{sj}}{\partial f_s / \partial x^0_{si}} = \frac{\partial x^0_{si}}{\partial y_{sj}}$$

$$\text{or } \frac{\partial E_s}{\partial y_s} \bigg/ \frac{\partial K_s}{\partial x^0_{si}} = \frac{1 + \lambda}{\theta}$$

$$\text{or } ME_{sj} / MK_{si} = (1 + \lambda) / \theta MP_{sij}$$

i.e., the ratio of the marginal efficiency benefit from jth product to the marginal cost of the ith fixed input is inversely related

to the marginal productivity of the i th input for the j th output in equilibrium.

$$\text{and } \frac{\partial E_s}{\partial y_{sj}} \left/ \frac{\partial M_s}{\partial x_{si}} \right. = - \frac{\partial f_s / \partial y_{sj}}{\partial f_s / \partial x_{si}}$$

$$\text{or } ME_{sj} / MM_{si} = 1 / MP_{sij}$$

i.e., the ratio of the marginal efficiency benefit from the j th product to the marginal cost of i th variable input bears an inverse relation in equilibrium to the marginal productivity of the i th input for the j th output.

We now turn our attention to the principle for dividing the overall budget into sub-budgets for the system units comprising the total programme. Defining the present value of net benefits, dependent on the size of the sub-budget K_s , as $B_s(\bar{K}_s)$, we seek to divide the total budget $\bar{K}$ among the systems in such a way that the total net benefits

$$\sum_{s=1}^S [B_s(\bar{K}_s) - \bar{K}_s]$$

are maximised subject to the budgetary constraint

$$\sum_{s=1}^S \bar{K}_s = \bar{K}$$

Forming the Lagrange expression

$$L = \sum_{s=1}^S [B_s(\bar{K}_s) - \bar{K}_s] - \lambda \left(\sum_{s=1}^S \bar{K}_s - \bar{K} \right)$$

we obtain the maximizing condition

$$\partial L / \partial \bar{K}_s = dB_s / d\bar{K}_s - 1 - \lambda = 0$$

$$\text{or } dB_s / d\bar{K}_s = 1 + \lambda \quad s=1, \dots, S$$

i.e., the marginal benefit-cost ratios should be the same for all systems.

The design and allocation problems are however interrelated. The net benefit function used in the allocation problem is dependent on the level of the budget allocated to a system. For each level of budget there is an optimal design for the system yielding a particular value of the benefit function. The planners need to know all the values of the benefit function for different levels of outlay on the systems which they have to combine over the systems in a way that maximum returns are obtained.

The standard methods of calculus are of no avail in treating problems of this nature. There are a number of reasons why the methods of calculus prove inadequate. The limitations are as follows.

An optimisation problem in calculus assumes free variability of the variables. This assumption does not hold when the values of some of the variables are bounded by constraints. The maxima may then occur at a point where the usual necessary conditions for optima are not satisfied.

In problems where a number of equations defining the constraints are smaller than the number of unknown variables in the system, the solution of the problem requires additional criterion of selection of the optima from among all possible solutions. Such problems are resolved by introducing inequalities and the technique of linear or non-linear programming is adopted to find the optima.

We present here an illustration from the French experience [6] where the technique of linear programming was used to select the best system of power plants to serve given levels of power demand at a given time.

The objective was to minimize the cost of production of power energy under assumed prices of the factors of production. The planners had at their disposal five groups of homogeneous plants : (1) steam plants, (2) hydro-electric plants with no reservoir, (3) hydro-electric plants with a large reservoir, (4) hydro-electric plants with a small reservoir and (5) tidal plants.

The performances of the plants of the different types were standardized to a "unit plant" with given level of capacity. The performance characteristics considered for such unit plants were

a_1 , average power output during the peak-winter months

b_1 , peak power output

c_1 , annual power output.

The problem posed consists in determining a programme of equipments meeting the requirements A_0 level of average outputs, B_0 level of peak power outputs and C_0 level of annual power outputs at the end of a five year plan period.

The total cost of a power plant consists of the initial costs of investment and the aggregate present value of the operating expenses over the life of the plant discounted at a given rate of interest. Assuming, for simplicity, constant operating costs f , the total discounted cost corresponding to the unit size is of the form

$$g = d + kf$$

where d is the initial cost of investment and k , the coefficient of capitalization.

The problem is formulated in the linear programming form as follows.

$$\text{minimize } x_1 g_1 + x_2 g_2 + x_3 g_3 + x_4 g_4 + x_5 g_5$$

Subject to the constraints on the load structure

$$a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4 + a_5 x_5 \geq A_0$$

$$b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_5 x_5 \geq B_0$$

$$c_1 x_1 + c_2 x_2 + c_3 x_3 + c_4 x_4 + c_5 x_5 \geq C_0$$

and the constraint on the total investment expenditure

$$d_1 x_1 + d_2 x_2 + d_3 x_3 + d_4 x_4 + d_5 x_5 \geq D_0$$

where D_0 indicates the level of expenditure authorized.

It is instructive to follow how the structure of the optimal solution is affected by a change in the level of the budgeted expenditure in problems of this type. The following table shows the change in the optimal solution with increase in the level of expenditure D_0 .

Table

Variation in optimal solution due to variation in the budgetary constraint

D_0 (Billion francs)	average power (MW)					total discounted cost	
	1	2	3	4	5	(Billion franc)	index
0							
195	2006	0	0	0	0	543	100
207	1324	0	0	0	368	479	88
227	635	0	726	0	331	456	84
319	0	0	493	0	1199	415	76
360	0	0	0	0	1692	404	74
621	0	1259	0	0	433	375	69
	0	1259	0	0	433	375	69

The table shows that no plan is possible below 195 billion francs. At this level of the budget the solution is composed of steam plants only. Beyond this level, at 207 and 227 billion francs, the tidal plants are introduced first with the steam plants, then with hydro-electric plants with a large reservoir. At the successive stages the importance of the ideal plants increases at the cost of the steam plants and the hydro-electric plants. The tidal plants stabilize at 433 Mw output after the expenses pass 620 billions. The cost decreases from 543 billion to 375 billion francs as D_0 increases up to 621 billion francs.

The data bring out the fact that techniques which are apparently cheaper from considerations of immediate investment cost are more often costlier than the others from long term considerations. As one notes the total discounted cost declines as possibilities of more profitable combination of

techniques are opened up because of relaxation on the budgetary constraints.

The foregoing illustration concerns the working out of one investment plan and takes the technological data for the different types of plants as given once for all. As, however, the limit of the plan period is extended over longer time one has to take into account the possibilities of changes in these coefficients due to technological progress. We present here a model developed for long term planning (6). As the period considered is long enough, the level of demand can also be assumed to increase with the expansion of the economy. The choice of the size of the plants is directly related to the level of demand. As the economies of scale become attainable with increase in the level of demand, one may consider the possibility of investing on more capital intensive techniques. In the sphere of power technology, plants of certain types, like the nuclear plant, come to compete with other types, when the volume of demand attains a reasonable level.

In this problem the plants are available in given size units only. The choice of the plants need now be made in terms of discrete units of different sizes. The technique of programming adopted for such problems is known as integer programming methods.

The budget in the present model is taken to be fixed over the whole period. One has to consider the problem of allocation of the budget appropriately over the time as also over the different techniques of production.

It may be difficult in a long period plan to estimate the details of the load structure for the successive periods. It is convenient to consider the average power output of the plants for such purpose. We determine the plant sizes by their capacity to produce average outputs. We assume that the capital units are worked at an efficient level, given the plant

factor, in optimal combination with the variable inputs over their life times.

The constraints on the productive capacity of investment in each of the periods are determined by the growth of demand in the economy, which is assumed to be given exogenously. The model relates to a situation where the long-term growth in demand is estimated from the projected growth of national income and the elasticities of demand for the various products. We consider here the case of an underdeveloped economy where a central authority is trying to foster a rapid growth of the economy by planning for development of the important sectors of the economy. A characteristic feature of such an economy consists of the rapid growth of demand for the various products which tends to outrun the growth in the productive capacity of the industries. The volume of savings generated by the economy rarely keeps pace with the growing requirements of the capital funds. The budgeting of the scarce resources to the different projects can be considered as a method of allocation of the resources, following some criterion for objective, by a central authority. It is likely that, under such conditions, many of the projects would find the resources allocated to them inadequate in relation to their requirements. The issue of excess capacity in a project merits careful consideration in this context. The issue of excess capacity in a project cannot be treated in isolation from the rest of the economy. There is some opportunity cost involved in the resources locked up in idle capacity in any project. The central authority, which is responsible for co-ordinating the activities of the different projects, has to decide the levels of excess capacity that might be tolerated in the various projects on the basis of the opportunity cost of the resources in alternative uses. The capacity constraints determined by the central authority serve therefore as one of the upper limits to the levels of investments in the different periods.

The problem can be formally represented by a coefficient matrix for Linear Programming as follows.

t	1	2	...	$\bar{t}$	...	T	
1	a_{11}	a_{12}					$\leq d_1$
2		a_{11}	a_{12}				$\leq d_2$
:							:
$\bar{t}$				a_{11}	a_{22}		$\leq d_{\bar{t}}$
:							:
T					a_{21}	a_{22}	$\leq d_T$
1	b_{11}	b_{12}					$\leq F_1$
2	b_{11}	b_{12}	b_{11}	b_{12}			$\leq F_2$
:							:
$\bar{t}$	b_{11}	b_{12}	b_{11}	b_{12}	...	b_{11}	b_{12}
							$\leq F_{\bar{t}}$
:							:
T	b_{11}	b_{12}	b_{11}	b_{12}	...	b_{11}	b_{22} ... b_{21} b_{22}
							$\leq F_T$
	r_{111}	r_{121}	r_{112}	r_{122}	...	r_{11T}	r_{22T} ... r_{21T} r_{22T}

The coefficients a_{ij} and b_{ij} in the matrix stand respectively for the productive capacities and the values of capital equipment for the i th technique of production and j th size of the units. The rows and the columns of the table are arranged in order of the time periods which run from periods 1 to T.

The course of technological change is reflected in the values of the coefficients a_{ij} and b_{ij} for the various periods. At period $\bar{t}$ an improved and more economic technique of production replaces the older equipment for the larger size ($i=1, j=2$).

By the T th period the older equipment for the smaller size ($i=1, j=1$) also gives way to improved types of equipment.

The first T rows in the table define the constraints on the levels of investments as derived from demand conditions for the different periods. We have in d_t the increase in demand over the successive periods, i.e.

$$d_t = D_t - D_{t-1}$$

where the D_t 's are the absolute levels of demand at each period. The d_t 's are assumed to be non-negative.

We further assume that the maintenance and replacement of old capital are taken care of independently, we can then relate the productivity of the new capital units with the increases in demand obtaining during the period. We ignore here any time-lag between investment and production. The condition regarding the availability of resources at period t is expressed by the relation.

$$F_t = \sum_i \sum_j \sum_{k=1}^{t-1} b_{ij} x_{ijk}$$

where $F_t = \sum_{k=1}^t f_k$ stands for the cumulated total of f_k , the resources available at each period k , upto the period t . x_{ijk} denotes the level of investment on the i th type of capital units of j th size in the period k .

The coefficients r_{ijt} denote the present value of the net returns expected over the life of capital units of the i th technique and the j th size installed in period t . The capital units are assumed to have a common length of life.

The values for r_{ijt} are obtained by discounting the series of net returns flowing from a capital unit during its lifetime in two stages. In the first stage, the returns over the lifetime of the capital unit, r'_{ij} is obtained from the relation

$$r'_{ij} = \sum_{m=1}^L r''_{ijm} (1+p)^{-m}$$

where r''_{ijm} is the return from the i th technique and the j th size of the capital unit in the m th year of its life which extends to L years, and p , the rate of interest used for discounting.

In the second stage,

$$\begin{aligned} r_{ijt} &= r'_{ij} (1+p)^{-t} \\ &= \sum_{m=1}^L r''_{ijm} (1+p)^{-(m+t)} \end{aligned}$$

The problem now is to find the investment levels x_{ijt} over T periods so that $\sum_i \sum_j \sum_t r_{ijt} x_{ijt}$ is maximized subject to the given constraints. Further, x_{ijt} 's can assume integer values only.

The problem may be posed in matrix form as follows

$$\begin{aligned} &\text{maximise } r'x \\ &\text{subject to } \begin{bmatrix} A \\ B \end{bmatrix} x \leq \begin{bmatrix} d \\ F \end{bmatrix} \end{aligned}$$

where A and B are partitioned matrices of the linear programming table and d and F are the correspondingly partitioned vectors of the constraint values.

A variant of the above model can be formulated where the capacity constraints require the satisfaction of minimum level of demand in each period as in the first illustration.

The model in the illustration was applied to the data adopted from Indian economy (7). The project authority was required to plan investments on power plants over an 18 year period within which the competitive position of the nuclear plant as against the thermal plant would be established.

In the models considered before, the level of demands were exogenously given. It was assumed that the supply of power by the project did not affect the level of its demand. In the following model presented in [8], this condition is relaxed. It is assumed that the project is connected with the rest of the economy in such a way that there is a recursive relation

between the demand for the outputs of the project in any period and the supply of the outputs by the project in the preceding period. As the output of the project is supplied as inputs to the other firms in the economy, it imparts a push on their levels of operation. The impulse is transmitted to the other sector of the economy through the linkage coefficients. The supply of the project only goes to whet the appetite of the economy as it were, and the additional demand for power is fed back into the system. We introduce a lag of a unit time interval between the supply of power and the additional demand for it. The latter is supposed to increase in period t by a fixed percentage of the supply provided in period $t-1$. No lag is assumed between investment and production. However, the response to additional demand by investment, at whatever level chosen, is instantaneous.

The decision variables in our problem are the units of the fixed capital equipments standing for productive capacities and varying in techniques of production as before. In the earlier years of the period under consideration there is only one type of capital equipment available for setting up. It is presumed, from some fore-knowledge of technical changes, that a new and more economical type of capital equipment would become available after the time period $\bar{t}$.

We assume that the maintenance of capital is taken care of independently. By the assumption of demand being induced by supply, the capital equipments once set up can be maintained continually. The values of the relevant coefficients are changed as more profitable techniques of production become available.

The objective of the model is to determine under such conditions the best plan of investment of the resources so that the growth of the firm, and thereby the part of the economy dependent on it, is maximized. The objective is attained by maximizing the aggregate returns from investments subject to the constraints stated.

The following programming tableau would represent the model.

t	1	2	...	T	
1	a_{11}				$\leq S_0\rho$
2	$-a_{11}\rho$	a_{11}			$\leq S_0\rho$
...	...	...			...
$\bar{t}$	$-a_{11}\rho$	$-a_{11}\rho$	$a_{21}a_{22}$		$\leq S_0\rho$
...	...	...			...
T	$-a_{11}\rho$	$-a_{11}\rho$	$-a_{21}\rho - a_{22}\rho$	$-a_{21}a_{22}$	$\leq S_0\rho$
1	b_{11}				$\leq F_1$
2	b_{11}	b_{11}			$\leq F_1$
...	...	...			...
$\bar{t}$	b_{11}	b_{11}	$b_{21}b_{22}$		$\leq F_1$
...	...	...	...	...	...
T	b_{11}	b_{11}	$b_{21}b_{22}$	$b_{21}b_{22}$	$\leq F_1$
	r_{111}	r_{112}	$r_{11\bar{t}}$	r_{12t}	$r_{21T} r_{22T}$

where

a_{ij} = productive of i th type and j th capacity capital unit.

b_{ij} = outlay needed (cost) for capital unit ij .

S_0 = the level of supply in the initial period (0).

S_{t-1} = the level of supply in the preceding period.

ρ = the rate of increase in demand, applied over supply.

F_1 = volume of investment fund available initially.

r_{ijt} = net return over life-time of capital unit ij installed in t .

The coefficients a_{ij} and b_{ij} in the table stand respectively for the productive capacity and the value of capital equipment for the i th technique of production and the j th capacity of the units. The rows and the columns of the table are arranged in order of the time periods which run from periods 1 to T. The objective is to maximize $\sum_i \sum_j \sum_t r_{ijt} x_{ijt}$ subject to the given constraints

The course of technological change is reflected in the values of the coefficients a_{ij} and b_{ij} for the various periods. At period $\bar{t}$, improved and more economic types of equipments replace the older equipments.

The rows in the upper half of the programming tableau refer to the demand constraints for the different periods. They are obtained in the following way.

The level of demand in any period t is given by

$$D_t = S_{t-1} + S_{t-1} \rho = S_{t-1} (1 + \rho)$$

where D_t is the level of demand generated in period t through S_{t-1} the level of supply, i.e., the level of production, in period $t-1$. Production in any period t is required to satisfy, to the extent possible, the demand generated in the period t .

The first row in the table gives the condition of demand for the first period. Expressing by x_{ijt} the units of investments on the i th type and j th size of capital at time t , we get

$$a_{11} x_{111} \leq S_0 \rho$$

where $S_0 \rho$ is the volume of additional demand given for the first period.

Introducing a slack variable s_1 for the difference between S_0 and the actual production in period 1, we can express the the first row in the table as

$$a_{11} x_{111} + s_1 = S_0 \rho$$

The level of additional production in the first period is, therefore, determined by the relation

$$a_{11} x_{111} = S_0 \rho - s_1$$

The level of total production in period 1 is now given by

$$S_0 + a_{11} x_{111} = S_1$$

The increase in the volume of demand in period 2 over the supply in period 1 is then obtained as

$$D_2 - S_1 = S_1 \rho = (S_0 + a_{11} x_{111}) \rho$$

where D_2 denotes the level of demand in period 2 and S_1 the level of supply i.e., the level of demand actually satisfied in period 1. Investment in period 2, is required to be made with a view to meet this increase.

The relation for the second period would appear as

$$a_{11} x_{112} = S_0 + a_{11} x_{111}$$

$$\text{or } -a_{11} x_{111} + a_{11} x_{112} = S_0$$

which corresponds to the second row of the programming matrix.

The general relation for period t in the upper half of the table is given by

$$\sum_i \sum_j a_{ij} x_{ijt} - \sum_i \sum_j \sum_{k=1}^{t-1} a_{ij} x_{ijk} \leq S_0 \rho \quad \text{for } t = 2, 3, \dots, T$$

$$\sum_i \sum_j a_{ij} x_{ijt} \leq S_0 \rho \quad t=1$$

The rows in the lower half of the programming matrix refer to the constraints on the resources over the periods.

The level of resources for the firms in case (i) is given by F . The availability of resources in any period t is given by

$$F - \sum_i \sum_j \sum_{k=1}^{t-1} b_{ij} x_{ijk}$$

A variant to the above model can be suggested where the budgetary resources allowed to a project authority could be augmented by the ploughing back of the returns, or a part of it, into the total fund. In the models of the present type, however, this would lead the project authority to prefer exhaustion of the resources to the limit of demand whenever such an opportunity presents itself, since investments in earlier periods would be rewarding in two ways. It would increase the demand for the subsequent periods as well as augment the current investment fund.

Numerical illustrations to the models are given in (8).

The above analysis shows the richness of the programming techniques in solving complicated problems and clarifying ideas in power planning.

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